MODERN SCIENCE TEACHING

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SCIENCE EDUCATION BEGINS IN THE ELEMENTARY SCHOOL (GLENS FALLS, N. Y., PUBLIC SCHOOLS).

MODERN SCIENCE TEACHING

A REVISION OF *MODERN METHODS AND MATERIALS FOR TEACHING SCIENCE*

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PREFACE

The purpose of this book is twofold (1) to serve as a textbook for those courses in methods of teaching science which are now being given in many colleges and universities; (2) to serve as a source book for teachers of science, supervisors of science and science educators, at whatever level they may be working, who wish to keep abreast of present trends in the teaching of science.

In many places there still lurks the shadow of the mistaken idea that anyone who has been taught can teach. Belief in this point of view, and the use of teaching methods derived therefrom, may be the cause of considerable poor science teaching. To teach effectively one must know. But knowing carries far more subtle implications than just knowing science. It means knowing something of the art of teaching, something of the social and economic implication of science; something of the nature of child development and many other things.

It seems reasonable to believe that the young and inexperienced person just coming into the field of science teaching should be given some opportunity to gain a perspective and to plan wisely for his career. The authors believe that the various sections and chapters of this book offer this opportunity for the new teacher.

In every profession there are so called "tricks of the trade." To many experienced science teachers, little can be more challenging than to discover that there may be another way of doing the prosaic thing he has done for years. Or perhaps someone has uncovered some new materials that will make the lesson more effective and meaningful to the pupils. The authors claim no priority on new ideas but hope that the results of their long and varied experience in teaching, which is inevitably woven into the lines of this book, may here and there, prove helpful to experienced teachers.

The book is divided into three sections: Section one is devoted to the principles of science teaching. Section two considers the problem of science rooms and equipment. Section three is concerned with a treatment of visual and other sensory aids used in teaching science.

During the course of preparing this book it was necessary for the authors to avail themselves of the contributions of a large number of people. The authors acknowledge their indebtedness to all who have done pioneering work in laying a foundation for a science of teaching science. The following persons deserve special thanks for contributions which have enhanced the value of this book; Dr. J. Darrell Barnard, New York University; Dr. Martin L. Robertson of the Macmillan Co.; Miss Edith Selberg of the Colorado College of Education, Greeley, Col.; Dr. G. L. Bohn, Temple University; Mr. R. G. Burton, Williams, Brown and Earle, Inc.; Mr. Carl Garvin, Principal, East Haven High School, Conn.

The Authors

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SECTION I

Principles of Science Teaching

Chapter 1

DEVELOPING A POINT OF VIEW IN SCIENCE TEACHING

Many books have a plot or theme which runs through their pages. In a sense, this book is not different, for between its covers the authors seek to put down those things about the profession of science teaching which they hope will be of practical use to the beginning teacher as well as a stimulus to others who have been in the profession longer.

Not all who read these pages will agree entirely with what is said. Perhaps that is best, for it is out of the discussion of differences that real progress usually emerges. While differences of opinion on this or that aspect of science teaching may exist, in the final analysis we are all concerned with seeking the best in science education for the youth of America and with the progress of our chosen profession.

In science teaching, as in other professions, there is no *one* point of view. There are many schools of thought, each of which is based on ideas that have resulted from experience and constructive thinking. In a book such as this it would be unwise to set forth one school of thought as though it might be a panacea for all the ills that beset science teaching. Such a statement of point of view then would become fixed, and would not have elasticity and adaptability. A philosophy of science teaching at its best should be a guide, flexible enough to include the best that has come from the past and yet able to encompass the newer developments in the field. True progress in any field can come only by a gradual growth wherein the new is tempered with the best from the past, to produce a forward-looking present.

A point of view as a philosophy in any area is a personal thing, molded and shaped by individual experiences and backgrounds. In this chapter the authors will attempt briefly to review some of the major contributions to science education from the past as well as some from the present. It is hoped that this may serve, perhaps as a guide, perhaps as a stimulus for some who are attempting to formulate a personal point of view in this area. The values of a personal philosophy of teaching are far-reaching. It enables one to weave together the many diverse threads of experience and association into a meaningful pattern of relationships.

A Brief Resume of Science Education in America

The Latin grammar schools. Formal education in America began about 1635 with the founding of the first Latin grammar school. These schools were established as college preparatory schools for boys going into the professions. At the peak of their popularity about 1725, there were some four hundred such schools in America. The Latin grammar schools gradually died out because of their failure to meet the needs of the times. There appears to be no record of any science offerings in the curriculum of the Latin grammar schools.

The academies. The Latin grammar schools were gradually replaced by public Academies which began about 1750 and became the dominant type of secondary school until about 1850. At the height of their development there were about six thousand such academies in America. This type of school was established largely in protest of the narrow curriculum of the Latin grammar Schools. They were intended to meet the needs of the boys and girls not going to college and thus offered curricula that were much more practical.

Science education in America began in the academies: natural philosophy, a forerunner of physics, was included in the curriculum of the first academy established by Benjamin Franklin in Philadelphia in 1751.

The early high schools. The free public high school grew out of the academy movement, beginning about 1821 with the establishing of the English High School in Boston. The growth of the high school movement was steady but slow until the opening years of this century. Since that time the development has been rapid in numbers, population, and the breadth of curriculum offerings.

The science offerings of the early high schools were influenced by the sciences taught in the academies. These consisted, for the most part, of natural philosophy, natural history, and chemistry. Each of these sciences was in the curriculum of the first American high school founded in Boston in 1821.

Natural philosophy had its beginnings in the European schools and was brought to America and included in the curricula of the earliest academies. It consisted of materials selected from the fields of physics, astronomy, and earth science. It remained as a part of the curriculum of the high schools until about 1872. The textbooks on natural philosophy indicate that the authors were interested primarily in acquainting the student with the practical aspects of the science. The treatment was largely descriptive and there was little or no laboratory work. Many of the books were inductive in their method. A topic was introduced with a problem, which was not explained. The topic usually ended with a statement of a principle. Some of the early textbooks went through as many as 40 editions.

Chemistry was offered as an elective subject in the curriculum of the English High School in Boston in 1821. It appears that chemistry had a rather uncertain place in curricular offerings generally. Some high schools had it while others did not. It is reported that by 1854, 26.6 per cent of all high school students in Ohio were enrolled in classes in chemistry. There was little or no laboratory work done by the students prior to 1860 since many schools had difficulty in getting apparatus and chemicals.

The natural history offered in the early academies and high schools was made up largely of botany and zoölogy. There was, however, no integration of these as we now have in the high school biology course. The emphasis was on the learning of facts. Considerable attention was given to the physiology and morphology of plants and animals.

An appraisal of the science education of the first fifty years of the high school movement would seem to indicate that the courses were taught primarily for their practical and informational values. There was little laboratory or demonstration work, and great emphasis was placed on the memorization of factual material. The courses were popular and were taken by many students who were not going to college. While some of the textbooks of the period were inductive in their development, most of the teaching was done by the lecture and recitation methods.

The period of college domination, 1872–1900. In 1872 Harvard College announced that physics and other high school sciences would be accepted for college entrance. Within a few years most of the colleges had followed the lead of Harvard. Soon the colleges were setting standards and requirements. The most influential of these standardizing documents was the Harvard Descriptive List issued in 1887. This was a listing of forty-six acceptable experiments in physics for college entrance.

During this period the offerings in high school science gravitated toward the colleges. Courses of study were prepared by college teachers of science and many of the textbooks were written by them. The textbooks in high school science became simplified and condensed college courses having little value beyond that of entrance to college.

The narrowing influence of the college domination of high school science extended well down into the early years of the present century. In fact, the influence may even now be discerned in a few of the textbooks that are still used in high school science.

Between 1890 and 1900 there was a movement toward standardizing requirements for entrance to college. This movement had its beginning in the report of the Committee of Ten, of the National Education Association in 1893, and gained impetus with the reports in 1896 and 1899 of the Committee on College Entrance Requirements, of the same organization. The movement toward standardization culminated in 1900 in the organization of the College Entrance Board. These Committee reports had a far-reaching effect in the teaching of high school subjects and especially in the high school sciences. Prior to these reports, schools had been offering short term courses in many sciences such as physics, chemistry, astronomy, geology, botany, zoology, and physiology. The Committee of Ten, and later the Committee on College Entrance Requirements, condemned the practice of short courses and recommended full year courses in fewer sciences. As a result of the work of these Committees, the first science sequence for high schools came about. The courses proposed were:

First year—physical geography
Second year—biology
Third year—physics
Fourth year—chemistry

There were some beneficial results from the college domination of high school sciences. As Mann[1] points out:

> The influence of the Descriptive List on the development of physics teaching in America has been tremendous. It appeared at the psychological moment when the demand for object teaching had reached its full force. It exalted this demand for object teaching into a requirement of quantitative laboratory work. It showed teachers and school boards how a laboratory method of teaching could be introduced into the work in physics with the use of materials at hand and with a small outlay for equipment. As a result of this movement the American public high schools now have laboratories while France and Germany are just beginning to secure them.

Twiss[2] sums up the effects of the period of college domination of high school science as follows:

> As far as science is concerned the results have been both good and bad. Among the good results are the establishments of the principles (1) that high school teachers should have adequate collegiate training for their work, (2) that laboratory work, field excursions, and some reference book work should be carried on in connection with each of the sciences, (3) that schools should be adequately equipped with laboratories, apparatus, and libraries for such work, (4) that double laboratory periods should be provided in the time schedules for the laboratory exercises (5) that laboratory notes should be systematically entered in suitable books by the students (6) that pupils should be taught not merely to memorize but to think. Among the bad results

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[1] Mann, C. R., *The Teaching of Physics,* Macmillan Co., New York, 1917, p. 58.

[2] Twiss, G. R., *Principles of Science Teaching,* Macmillan Co., New York, 1922, p. 188.

have been (1) the tendency to cast all instruction in one mold in the attempts to meet the specifications of syllabi and examinations (2) over-emphasis on the assimilation of subject matter, and the consequent undervaluation of the scientific method of study, by means of which the subject matter of science is best acquired, and (3) worst of all discouragement of initiative on the part of school teachers and administrators because of the burdensome amounts of subject matter that were called for by these authoritative syllabi.

The period of expansion and readjustment, 1900–1920. In the closing years of the last century a rapid increase both in the number of high schools and in the high school population was begun. This movement gathered force in the first decade of this century and reached a peak between 1910 and 1920. The tremendous influx of students into the high schools created many problems. But most important among these was the failure of the college-prescribed curriculum to meet the needs of young people.

The demands for a different type of curriculum to meet more adequately the needs of the changed high school population was in part the cause of the junior high school movement. In the older scheme, schools had been organized almost universally on a plan which had eight years of elementary training and four years of high school training. Between 1900 and 1910 some schools began to organize on a basis which called for six years of elementary school training, three years of junior high school training, and three years of senior high school training.

The science offerings in the high school also experienced some changes, about this time, in an attempt to meet both the needs of the changed high school population and those of the newer junior high schools. Perhaps the most significant change was the introduction of general science to replace physical geography as the first year subject of the four year science sequence. This change came about in an attempt to meet the need of a terminal course in science for students not going to college and also to provide an exploratory course for the later specialized sciences.

In some of the newer junior high schools the science offerings were pushed down into the seventh and eighth years. This had the effect of increasing the opportunities for science experience over a longer period of schooling. In the course of a few years, general science largely replaced physical geography in the science program and was enrolling a larger percentage of the total high school population than any of the older and more specialized sciences.

The trend toward change, to meet more adequately the newer demands on the high school, moved slowly, but was considerably accelerated by the reports of the Commission on the Reorganization of Secondary Education[3] of the National Education Association. A report on the reorganization of science in the secondary schools was issued by a sub-committee of this Commission.[4] This report was the first comprehensive document to deal exclusively with the teaching of science and although it was confined to science in the secondary school, it constituted one of the land marks of science teaching in American schools.

The report sought to show how science instruction could contribute to the cardinal principles of secondary education set up as objectives by the Commission; to bring some order to the science offerings of the high school; and to give practical help on the selection and organization of materials, and on the teaching of science in the high schools. The report had the salutary effects of giving impetus to an emerging science sequence in the high schools, as well as pointing science instruction toward larger social goals than had been true previously. Some critics believe that the report tended to overemphasize immediate and practical goals to the exclusion of certain of the larger influences that the accumulation of science knowledge had on our present civilization.

A committee of the American Association for the Advancement of Science in 1927 issued a report entitled "On The Place of Science in Education."[5] This report emphasized the importance of scientific thinking as an objective of science teaching; recommended that studies of a national scope on science teaching be set up; and urged that a field secretary be provided to assist teachers of science in the study of their problems.

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[3] *Cardinal Principles of Secondary Education.* Report of the Commission on the Reorganization of Secondary Education of the National Education Association. Bulletin No. 35. United States Bureau of Education, Washington, 1918.

[4] Commission of the Reorganization of Secondary Education. "Report of Subcommittee on the Teaching of Science." *U. S. Bureau of Education Bul.* No. 26. Government Printing Office, Washington, 1920.

[5] American Association for the Advancement of Science, "Committee Report on the Place of Science in Education." *School Science and Mathematics,* XXVIII (June 1928).

Another influential report in science education was issued in 1932 as the Thirty-first Yearbook of the National Society for the Study of Education.[6] This report advocated for the first time a twelve year science sequence beginning in the elementary school and extending through the high school. It also advocated that science instruction on all school levels be organized around certain broad concepts or generalizations. The report stated thirty-eight such principles as guides in the selection of specific objectives for science teaching. The influence of this report has been far reaching in that it has given impetus to the introduction of science into the curriculum of the elementary school and has gone a long way toward promoting the organizing of science courses in terms of larger principles.

As a part of the National Survey of Secondary Education, in 1932, a bulletin entitled "Instruction In Science"[7] was published. This report was based on observations in 14 cities over the country and upon evidence obtained from the analysis of a large number of courses of study in each of the four high school sciences. The investigation indicated a great lack of agreement in aims, content, and method, among the science educators and the teachers of science. The investigation also revealed that general science and biology were well established in the high school curriculum and were more forward looking both in aims and methods than the older sciences of physics and chemistry.

In 1938 the Commission on Secondary School Curriculum of the Progressive Education Association issued a report entitled "Science In General Education".[8] This report advocated that science in the secondary school be taught around broad areas of living such as (1) personal living, (2) immediate personal-social relationships, (3) social-civic relationships, (4) economic relationships, (5) the disposition and ability to use reflective thinking in the solution of problems. The report traced the implications for science teaching in each of these proposed areas of living.

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[6] *Program for Teaching Science.* Thirty-first Yearbook of the National Society for the Study of Education, Part I, Distributed by the University of Chicago Press, Chicago, 1932.

[7] Wilbur L. Beauchamp, "Instruction In Science." *U. S. Office of Education Bulletin,* 1932, No. 17, Monograph No. 22, Washington, Government Printing Office, 1933.

[8] Progressive Education Association. "Science In General Education." D. Appleton Century Co., New York, 1938.

The National Committee on Science Teaching of the Department of Science of the National Education Association, after a three year period of study, issued a series of reports in 1942. Two of these reports had to do with the changed emphasis in the teaching of science in America. These were entitled "Science Teaching for Better Living"[9] and "Redirecting Science Teaching in the Light of Personal-Social Needs."[10] These reports were significant because they were prepared by Committees of Science teachers and were participated in by many other science teachers over the country. The reports advocated somewhat the same point of view as that of the Progressive Education Association report mentioned previously, however, they went farther in suggesting that pupils have science needs in such areas of living as safety, conservation, health, and vocation. The trend of teaching science for purposes of general education was further emphasized by a report published in 1944 entitled "Education for All American Youth"[11] and by another report published in 1945 entitled "General Education in a Free Society."[12]

The recommendations of these two reports as they related to science were well summarized in the Forty-Sixth Yearbook of the National Society for the Study of Education[13] as follows:

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[9] American Council of Science Teachers, National Committee on Science Teaching. "Science Teaching for Better Living" National Education Association, Washington, 1942.

[10] American Council of Science Teachers, National Committee on Science Teaching, "Redirecting Science Teaching in the Light of Personal-Social Needs." National Education Association, Washington, 1942.

[11] Educational Policies Commission, "Education for All American Youth" National Education Association, Washington, 1944.

[12] Harvard University, "General Education in a Free Society" Harvard University Press, Cambridge, 1945.

[13] *Science Education in American Schools,* Forty-Sixth Yearbook of the National Society For the Study of Education, Part I, University of Chicago Press, Chicago, 1947.

(a) Science instruction should begin early in the experience of the child.

(b) All education in science at the elementary and secondary levels should be general. Even for students going to college, general courses in biological science and in physical science (according to the Harvard report) "should make a greater contribution to the students general education and his preparation for future study than a separate one-year course in physics and chemistry." The document of the Educational Policies Commission goes even further in its recommendations for reorganization of high-school science courses.

(c) The development of competence in use of the scientific method of problem solving and the inculcation of scientific attitudes transcends in importance other objectives in science instruction.

In 1947 the National Society for the Study of Education published its Forty-sixth Yearbook entitled "Science Education in American Schools."[14] This report stresses the importance of science taught for its functional value in aiding the adjustment of individuals. It recognized and endorsed the present science sequence through the elementary and high schools. It urged support for the growing tendency to offer physical science in the high school for those pupils not going farther in the study of science. The objectives for science study proposed by the report are cited in detail in Chapter 2.

The Influence of Science in Present-Day Living

The youth of today must adjust themselves to a much more complex and chaotic world than existed a generation or even two decades ago. We are living in a fast-moving age in which strong forces are tending to produce rapid changes. Young people have become so accustomed to the phrase, "we live in an age of science," that they tend to take it for granted and rarely stop to reflect on the premises which lie back of this generalization.

An individual in this present-day world may be likened to a cork on a turbulent ocean being buffeted about by the ever-changing forces of wind and tide. The traditions and customs of our social order drive one now with and now against the forces of a rapidly changing physical environment often caused by advances of a technological nature. In this chaotic scene the individual is confronted with the urge to resolve it for himself and the immediate need to adjust to its ever-changing patterns.

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[14] *Science Education in American Schools.* National Society For the Study of Education, Part I. University of Chicago Press, Chicago, 1947.

One need consider only a small sampling of the factors at work in present-day life to secure convincing evidence that we are living in an age of rapid change and that science is playing a dominant part in bringing these changes about. We have witnessed a second world war in which the carnage and devastation wrought by technological advances that produced guided missiles, jet propulsion, and atom bombs, was unparalleled in human history. Television has become commonplace and may be slowly changing the entertainment habits of large segments of the population. Travel by air has now reached out and linked us with the remotest corners of the earth. Injury and death from automobile accidents continue to mount year after year. Frequent devastating floods in recent years, and the recurrence of severe dust storms in certain parts of the world, have made conservation an international problem. Indeed, the rapid depletion of the soil resources of the world, and the rapid increase of the population have brought us to the point where we must realize that there may be doubt concerning an adequate food supply in the near future if not in the immediate present. The discovery of atomic fission moved the world in a short time from an era of reasonable security into an era of uncertainty and doubt. We have seen that through the release of the tremendous energy of the atom, death and devastation can be dealt out to great masses in a matter of seconds. Some of our greatest scientists fear for civilization itself if atomic energy is to be the pawn of the militarists. On the other hand, we are beginning to sense dimly that through atomic energy we may be on the threshold of a new era when man will be further emancipated. From the studies now being carried on with radioactive isotopes new knowledge is being discovered that may aid us in the fight on disease and also help us better to understand processes which, up to now, have been obscure.

If one may prophesy, judging by the trends as evidenced in the past few decades, it seems reasonable to predict that forces of science, technology, and social change will play an increasingly important role in the lives of individuals. Thus, more and more, they will be confronted with problems which have causes deep-rooted in the area of science. The causal role of science as a basic factor in many of our present-day social and economic problems makes it mandatory for the science teacher to look for the ultimate goals of his instruction beyond the narrow confines of pure science to the social implications that result from technological advances. It is no longer sufficient to regard the end of educational procedures as preparing for some dimly visioned future. The young people whom we teach are experiencing life on every hand and must be conditioned to adjust to its forces and to solve the problems which are at their maturity levels,

The first reaction that one naturally gives to such social aspects of science as those mentioned above is that they are problems of large scope and are relatively remote from the lives of boys and girls. However, closer study reveals this to be a false assumption, for it is difficult to find a single element of social change which does not affect the immediate lives of boys and girls, creating real problems for them which they must solve. Thus science teachers are faced with the necessity of becoming sensitive to these problems of young people, and so setting the stage for learning that science materials will make a contribution to the solution of their problems.

Earlier in this chapter it was pointed out that the teacher must formulate a philosophy of teaching to suit his own conditions and needs, but he must guard against the possibility of this philosophy becoming rigid and fixed. It should be flexible, adaptable, and developing in its nature. Just as the scientist always holds his hypotheses subject to modification with the introduction of new evidence, so must the philosophy of a teacher develop and shape itself to the conditions and factors of social change.

The problems which confront boys and girls today are complex. This is true not only because the forces bringing about social and economic change are complex, but also because individuals have differing hereditary backgrounds, differing emotional patterns, differing needs, or differing sensory equipment to receive impressions from a given situation. This means that when a group of boys and girls are faced with the same situation demanding adjustment from all of them, we may expect many different types of behavior from the individuals in the group. This creates an extremely difficult situation from the standpoint of teaching, for one implication is that for maximum effectiveness we should have to make individual case studies in each adjustment situation. This, of course, would be impossible with our present educational setup and with most teachers being unqualified to make such studies.

The nearest approach we can hope to make at present toward helping students to adjust to the situations confronting them is to study the broad picture of present-day life and attempt to see the larger aspects wherein most of the boys and girls will find their adjustment problems. It will, moreover, be necessary to study carefully the behavior patterns of boys and girls of school age to see if any central tendencies regarding needs can be ascertained. Then from these broad studies it may be possible to block out certain general needs of young people in present-day society, with the result that science materials and learning experiences may be redirected to bring about a more effective adjustment to the problems growing out of these needs.

Reference has been made to the role which science and technology have played as antecedents for some of the social and economic conditions confronting us in present-day life. Involved in this fundamental relationship lies an obligation for science to share in making more effective the adjustments of boys and girls to these conditions which it, in part, has created.

A study of the aspects of present-day living which seem to have science antecedents or implications, and a study of the needs of boys and girls, as evidenced by their behavior patterns, would seem to reveal that there are many focal points, where science can aid in the adjustment of individuals. These focal points are in many ways characteristic of individuals for, as has been pointed out, no two individuals bring the same equipment to a situation demanding adjustment. Regardless of the complexity of the problem, there seem to be certain cleavages which make possible a description of the contributions science is peculiarly fitted to make in order to achieve a more effective adjustment for the individual.

In attempting to list the things that science can do in this respect, it is the purpose here to suggest only one possible grouping. In no sense is this list unique or exhaustive. Other, and equally as useful, listings have been made. Neither should the elements in the following listing be thought of as hard and fast, but rather that they are flexible and no doubt overlap at many points.

SUGGESTED CONTRIBUTIONS WHICH SCIENCE CAN MAKE TO THE ADJUSTMENT OF INDIVIDUALS

(1) Science can aid in the development of the social competence of individuals.
(2) Science can aid in the vocational guidance of individuals.
(3) Science can aid in the development of the physical and mental health of individuals.
(4) Science can aid in the education of individuals as potential consumers.
(5) Science can aid in the education of individuals as potential producers.
(6) Science can aid in the education for leisure time.
(7) Science can aid in the education of the individual in developing a philosophy of living.
(8) Science can aid in the education of the individual for maintaining personal safety.
(9) Science can aid in educating for the wise use of natural resources.
(10) Science can aid in the educating of individuals for solving problems.
(11) Science can aid individuals in developing a desirable group of attitudes.
(12) Science can aid individuals in developing a pattern of appreciations.

Science in the School Curriculum

As one attempts to shape a point of view in the area of science teaching, there are some things related to its place in the school curriculum which should be considered. Earlier in this chapter we discussed the influence of science and technology in shaping the world in which we live. It was suggested that young people who are in our schools are living in an environment constantly teeming with the products of an age of science. The things they use, the media which supply much of their entertainment, the books, magazines, newspapers, and even the "funnies" are constantly bringing them in contact with things that are related to science.

In a situation such as this, there should be no question as to whether science can justify its place in the curriculum of the modern school. And yet, in many places there is still great reluctance to giving science the time it should command in the education of every child. This tendency is especially true of science on the levels of the elementary schools. There can be little doubt but that science should have as much consideration, in this respect, as language study, social studies, or mathematics, all of which have sequences extending well down into the elementary school. In the junior high school levels the conditions are somewhat better. In many places where the school is organized on the six-six plan, general science is often offered in the seventh, eighth, and ninth years.

On the Senior High School level, general biology is well established as a tenth grade course and is usually offered as an elective for each of the three years. There is a considerable body of evidence available that seems to indicate that both general science and biology are going a long way toward meeting the needs of the young people. Improvement is always possible and no doubt these courses are being improved from year to year.

Physics and chemistry, usually offered as elective subjects in the eleventh and twelfth grades, are not so fortunate. Enrollment in these specialized courses has declined steadily over the years except for a slight increase during the war years.

In 1900 twenty per cent of the high school population studied physics. Today less than 6 per cent of high school students are enrolled. Only about half of the nation's high schools now offer the subject. Compared with the other high school sciences, of every 100 students enrolled in high school 20 take general science, 15 take biology, 7 take chemistry, and between 5 and 6 take physics.

Physical science, which is a fusion of physics, chemistry and other physical sciences, has come into the curriculum in many places in the last decade. There is at present too little evidence upon which to judge the effectiveness of this course, but its enrollment seems to be increasing each year. This course has very real potentialities for meeting the needs of boys and girls in this area much as general biology functions in the area of biological science.

In some places over the country there have been attempts to teach science in an integrated course. In some situations it has been taught with English and social studies while in others it has been offered with mathematics. These courses have not gained general favor, and the prevailing reaction among many science educators is that there is a danger that the work may be largely descriptive when the pupil learns *about* science rather than actually learning science.

The Tools of the Science Teacher

Every profession has certain tools without which an individual in the profession can not work efficiently and effectively. So it is with the person who chooses the field of science teaching. This discussion will assume that in his training the science teacher has attained those manipulative skills essential to carrying on the science work. Over and beyond these are certain professional tools that every teacher of science should become familiar with for they will make his work more effective.

The research studies in the field of science teaching. These studies are so numerous that any attempt to list them would be outside the scope of this book. However every person going into science teaching should become familiar with the three volumes of research studies in the area which have been assembled by Dr. F. D. Curtis.[15] The reported studies have been selected with great care and have been presented as digests in such a way that the method and results of the studies may be quickly read.

Current research in the field is reported in the following magazines:

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[15] Curtis, F. D., *Digests of Investigations In The Teaching of Science,* Volume I, II, and III., P. Blakiston & Co., Philadelphia.

(a) Science Education[16]
(b) The Science Teacher[17]
(c) School Science and Mathematics[18]
(d) The American Biology Teacher[19]

QUESTIONS AND EXERCISES

1. Discuss the changes in emphasis that have taken place in science education from 1820 to the present.
2. Show how a knowledge of the historical background of science teaching in America might be a factor in formulating a point of view.
3. Secure a copy of Bulletin 26, 1920 of the U. S. Office of Education entitled, "The Reorganization of Science In Secondary Schools," and make a careful study of it. Present your findings to the class.
4. Read and review before the class, the Thirty-first Yearbook of the National Society for the Study of Education.
5. Make a careful study of the Forty-sixth Yearbook of the National Society for the Study of Education. Present a review of your study to the class.
6. Compare and contrast the point of view represented in each of these three major reports.
7. Indicate how a careful consideration of the major reports in the area of science education might be an influential factor in formulating a point of view.
8. Show how a keen awareness of the part that science and technology are playing in our modern civilization might be a factor in formulating a point of view.
9. Make a searching analysis of your present feelings and attitudes toward science education, as well as of your understanding of what its trends seem to be. Out of this analysis write down a few statements that might be the beginnings of a personal philosophy or point of view. Discuss this with others in the class.

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[18] *School Science and Mathematics,* Glenn W. Warner, Editor, 7633 Calumet Ave., Chicago, Ill.

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Chapter 2

THE MAJOR GOALS OF SCIENCE TEACHING

The major goals of any subject in the school curriculum must, of necessity be aligned properly with the broad results sought for education in a democratic society. It would be outside the purpose of this book to review here the statements of general aims of education. It is assumed that these have been pretty well agreed upon by educators in general, and that they may be used here as a frame of reference. In this chapter the goals of science teaching will be examined with respect to trends, functions, and selection.

Trends in Objectives for Science Teaching

Nature study and its objectives. Following the Civil War nature study was introduced into the elementary schools of America as a subject of study. The movement grew rapidly and was about the only science offering in the lower grades until the introduction of elementary science in about 1925. There has been considerable controversy over the values of nature study as a subject in the curriculum of the elementary school. Considerable criticism has been directed toward the sentimentalism that was evidenced in the statement of its objectives, as well as toward the fact that it lacked continuity from level to level. There can be little doubt that, despite its acknowledged shortcomings, nature study did meet certain specific needs of young people.

The most complete listing of the objectives for nature study is to be found in the *Fourth Yearbook* of the Department of Superintendence of the National Education Association (1926). The list is too long to reproduce here. In this listing there are seventy objectives grouped under the headings Spiritual, Esthetic, Intellectual, Social, Civic, Economic, Vital, Avocational, Vocational, and Practical.

Trends in the objectives of elementary science. This subject was introduced into the curriculum of the elementary school about 1925. Since that time it has grown steadily under the impetus of several major reports in the field, all of which have endorsed a twelve year program for science in the schools. In contrast to nature study, elementary science offers a continuous and enlarging program of science instruction which embraces not only the biological sciences but the physical sciences as well. Some idea of the difference in aims between nature study and elementary science may be seen in the criteria used by one investigator in the field[1] for selecting objectives of elementary science:

A. Certain objectives that are selected for elementary science should conform to those scientific conceptions (1) which when understood, greatly influence the thought reaction of the individual; (and) (2) which have modified thinking in many fields.
B. Certain objectives that are selected for elementary science should conform to those goals (information, skills and habits) in science that are important because of their function in establishing health, economy, and safety, in private and public life.
C. Certain objectives that are selected for elementary science should conform to those facts, principles, generalizations, and hypotheses of science which are essential to the interpretation of the natural phenomena which commonly challenge children.

Later in this chapter some of the statements of objectives for elementary science will be examined.

Trends in objectives for general science. General science was introduced into the school curriculum late in the first decade of this century. In an early investigation of the objectives for this subject Crecelius[2] found the following to be most common:

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[1] Craig, Gerald S., "Certain Techniques Used in Developing a Course of Study In Science For the Horace Mann Elementary School," Reported in F. D. Curtis, *Second Digest of Investigations in the Teaching of Science,* P. Blakiston's Sons, Philadelphia, 1931.

[2] Crecelius, Philipine, "A Report on the Objectives of General Science Teaching," *School Science and Mathematics,* April 1923, Vol. XXIII, pp. 313–319.

(1) Acquaintance with elementary laws of nature necessary for the health of the individual and community;
(2) To give information about appliances which science has developed and which are useful in making for greater comfort and convenience in home and community;
(3) To give children opportunity to indulge in the playful manipulation of toys, tools, machines etc., in order that they may explore the world of reality;
(4) To provide opportunity for acquaintance with the simpler applications of science in public utilities in order that the individual may more adequately fulfill the duties of citizenship.

In 1924 Watkins[3] investigated the objectives for general science and his findings were in close agreement with those of four previous investigators. His list of objectives are:

To insure that the pupil acquires:

(1) An understanding and control of environment.
(2) A fund of information concerning nature and science.
(3) A preparation for later science courses.
(4) A training in the scientific method.
(5) A development of power of interpretation and application.
(6) A development of interest in science.
(7) Culture.

In 1927 Cureton[4] found the following to be the most important objectives for general science:

(1) Appreciation of the value and importance of science as it affects his daily life so that he may acquire the proper attitude toward those civic-scientific issues which he will later be called upon to lend his voice in solving.
(2) To develop in the child those general attitudes and habits of broad-mindedness, fidelity to truth, careful inquiry and evaluation of evidence in connection with problems and logical analysis of data, which will tend to mold his character and temperament in the best manner.
(3) To develop in the child an interest in the value, worth, and beauty of science, to the end that he may have opened before him a great number of interesting avocations and that he may be

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[3] Watkins, Ralph K., "The Technique and Value of Project Teaching in General Science," *General Science Quarterly,* Vol. VII, pp. 235–256 and Vol. VIII, pp. 311–341 and 387–422.

[4] Cureton, Edward E., "The Aim and Content of the Course of Study in General Science for the Junior High School." Master's Thesis (unpublished) Stanford University, 1927.

stimulated to go further into one or more of the many fields of scientific endeavor.

(4) To develop in the child those particular habits and attitudes, and to present to him those particular facts and principles, most likely to be of definite use to him both as a child and as an adult.

(5) To give the child a general preview of science to the end that he may have a better basis for the selection of further science work in in school and perhaps in life.

Later in this chapter more recent statements of objectives for the course in general science will be examined.

Trends in objectives for senior high school sciences. Before botany, zoology, and physiology were fused into the present course of general biology, the principal objective of these courses was informational. However, there has been a definite shift in aims and now the course tends to be much more functional and social in nature, tending to give the pupil an understanding of those biological principles which will function in such areas as health, safety, conservation, and the like. In some places the objectives for biology are influenced by the demands of college entrance examinations.

The aims for physics and chemistry have changed very little over the years. These courses are still greatly influenced by the demands of the colleges. However, in recent years there have been several notable attempts to make these courses more practical and functional in the lives of boys and girls.

The newer course in *general physical science* seems at present to have broken away from the objectives of physics and chemistry. In most places the course is taught for the values that it has for aiding young people in the adjustment to life problems. Another interesting trend in some of the courses in physical science is the emphasis placed on training in the abilities of problem-solving and in the development of desirable attitudes.

The Functions of Objectives in Science Teaching

Objectives, in any area of the curriculum, should be regarded as directions of growth, and not as ultimate ends to be completely reached. In this respect science is not different from other areas. It is important that objectives be selected toward which the growth and development of the individual may be directed. From a very practical point of view, objectives need to be selected and stated in such a way that progress toward their attainment may be appraised. That is to say, objectives are very closely related to evaluation procedures. Evaluation will be discussed in detail in a later chapter.

It would undoubtedly be possible to list many and diverse functions for objectives in science teaching. The following list is proposed only as suggestive of these functions and is not in any sense exhaustive.

Objectives for science teaching should:

(1) Be directed toward the general goals of education in a democracy.
(2) Consider the needs and interests of the learner.
(3) Be attainable at a given level of instruction.
(4) Serve as guides to the selection of learning materials.
(5) Serve as guides to the organization of learning materials.
(6) Should direct learning toward the modification of the behavior of the learner, that is, should be functional.
(7) Should serve to suggest ways of evaluation of progress toward their attainment.

Criteria for Selecting Objectives

With the multiplicity and diversity of adjustment patterns that seem to be demanded of young people living in a world so teeming with the effects and implications of modern science, it becomes essential to select objectives that are functional. This suggests that there is need for setting up certain criteria that may serve to identify both the adjustments that must be made and the objectives. The Committee for the Forty-Sixth Yearbook of the National Society for the Study of Education[5] has proposed the following list of criteria for selecting objectives . . . criteria employed in formulating the objectives are briefly these:

(1) —the statement should be practicable for the classroom teacher. It must be usable; when properly used, it should lead logically from one step to the next; and, if carefully followed, it should result in progress toward the objectives ultimately sought.

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[5] *"Science Education In American Schools,"* Forty-Sixth Yearbook of the National Society for the Study of Education Part 1. University of Chicago Press, Chicago, 1947.

(2) In the second place, the statement of objectives should be psychologically sound. It should be based on generally accepted principles of learning.
(3) In the third place, the objectives should be possible of attainment under reasonably favorable circumstances and to a measurable degree.
(4) In the fourth place, the selected objectives should be universal in a democratic society.
(5) Finally, the statement of objectives and the explanatory context should indicate directly, or by clear implication the relationship of classroom activity to desired changes in human behavior.

SOME SELECTED STATEMENTS OF OBJECTIVES FOR SCIENCE TEACHING

Earlier in this chapter a few selected studies of objectives were cited for the purpose of indicating the trends in objectives of some of the science subjects. At this point it seems desirable to give some consideration to more recent statements for the purpose of getting a clear picture of the present status of objectives for teaching science.

Croxton[6] has set up the following as general goals of science teaching, and then suggested that science in the elementary school should contribute toward their realization.

(1) To cultivate scientific attitudes and methods of procedure.
(2) To tend to broaden concepts, generalizations and outlooks.
(3) To open new avenues of interest and satisfaction.
(4) To enable the individual to meet the problems of existence with the available knowledge and requisite skills.
(5) To develop social attitudes and appreciations.

Blough[7] has stated the objectives for science teaching in the elementary school as follows:

(1) To help children to cultivate a scientific way of looking at things and to give them a sound method of procedure for solving problems.
(2) To teach them certain concepts and generalizations which they can use in interpreting what they see about them.
(3) To open new avenues of interests and satisfactions.
(4) To assist in the development of desirable social behavior.
(5) To aid in developing certain appreciation for the environment.

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[6] Croxton, W. C., *Science Teaching In the Elementary School.* McGraw-Hill, New York, 1937.

[7] Blough, Glenn O., "Elementary Science Objectives." *School Life.* October, 1948.

In a bulletin entitled "Teaching Elementary Science"[8] prepared for the Bureau of Education of the Federal Security Agency, the aims of science in the elementary school are stated as follows:

(1) To provide experiences as a means of forming science principles and generalizations.
(2) To help pupils apply these principles and generalizations to interpret things that happen around them.
(3) To give practice in the use of scientific attitudes and skills in problem-solving.
(4) To broaden their interests in the every day phenomena of their environment.

A careful and critical examination of these sets of objectives, selected as typical of recent statements for elementary science, will indicate that there is general agreement on the direction that science teaching should take on the elementary level.

To indicate more recent trends in objectives for general science three selections are cited. Watkins and Perry[9] propose the following, as objectives for general science:

(1) Pupils should develop a better general acquaintance with the natural science factors of their daily environment.
(2) Pupils should develop better understandings of the basic science principles underlying common natural phenomena and the application of these phenomena.
(3) Pupils should learn to make use of the findings of science as these affect their living from day to day.
(4) Pupils should build more effective controls of factors in their environment.
(5) A major function of school science training is that of aiding pupils in developing interests in natural phenomena, the social and industrial applications of scientific principles, and the work of research investigators.
(6) Pupils should form habits of reading intelligently the literature of science and current descriptions of scientific achievement.
(7) Pupils should learn to solve natural science problems for themselves.
(8) It is important that pupils in science class form appropriate scientific attitudes.

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[8] *Teaching Elementary Science,* Bulletin 1948, No. 4 Office of Education, Federal Security Agency, U. S. Government Printing Office, Washington, 1948.

[9] Watkins, Ralph K., and Perry, Winifred, *Teacher's Handbook,* to accompany Science in Our Modern World Series. Macmillan Co., New York, 1941.

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Beauchamp, Mayfield, and West[10] have set up the following objectives for general science:

(1) An understanding of those generalizations of science that a citizen of a modern democracy needs in order to solve every day personal, social, and civic problems;
(2) An understanding and appreciation of the importance to oneself and to society of the applications of scientific generalizations and discoveries;
(3) The development of scientific attitude of mind;
(4) Growth in the ability to do critical thinking;
(5) The development of wholesome intellectual interests and appreciations which lead to a desirable use of leisure time and which give a basis for educational and vocational guidance.

Caldwell and Curtis[11] propose the following as major objectives for the teaching of general science:

(1) To develop interesting, useful and enduring acquaintance with various aspects of science important in the modern world;
(2) To develop understandings of important scientific principles which the pupils may apply in their everyday lives;
(3) To provide abundant and guided training in the development of scientific attitudes and in the use of scientific method;
(4) To provide and develop scientific interests and knowledge of wide variety that will serve recreational and leisure uses during the study and in later life.

The *Forty-Sixth Yearbook* of the National Society for the Study of Education[12] has given a recent statement of objectives for science teaching in general. These may be used for securing an understanding of the present status of science aims for both the elementary and high school levels.

"TYPES OF OBJECTIVES FOR SCIENCE TEACHING"

A. Functional information of facts about such matters as:
  (1) Our universe—earth, sun, moon, stars, weather.
  (2) Living things—plants and animals.
  (3) The human body—structure, function, and care.
B. Functional concepts such as:

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[10] Beauchamp, W. L., Mayfield, John C., and West, Joe Young, *Teacher's Guidebook for Everyday Problems in Science,* Scott, Foresman, Chicago, 1941.

[11] Caldwell, Otis W., and Curtis Francis D., *Teacher's Manual for Everyday Science.* Ginn and Company, Boston, 1944.

[12] *Science Education In American Schools,* Forty-Sixth Yearbook of the National Society for the Study of Education, University of Chicago Press, Chicago, 1947.

    (1) Space is vast.
    (2) The earth is very old.
    (3) All life has evolved from simpler forms.
    (4) All matter is probably electrical in structure.

C. Functional undestanding of principles, such as:
    (1) All living things reproduce their kind.
    (2) Energy can be changed from one form into another.

D. Instrumental skills, such as ability to:
    (1) Read science content with understanding and satisfaction.
    (2) Perform simple manipulatory activities with science equipment.

E. Problem-solving skills, such as ability to:
    (1) Sense a problem.
    (2) Make the best tentative explanation or hypothesis.
    (3) Test the hypothesis by experimental or other means.

F. Attitudes, such as:
    (1) Open-mindedness, willingness to consider new facts.
    (2) Intellectual honesty—scientific integrity.

G. Appreciations, such as:
    (1) Appreciation of the contributions of scientists.
    (2) Appreciation of basic cause and effect relationships.

H. Interests, such as:
    (1) Interest in some phase of science as a recreational activity or hobby.
    (2) Interest in science as a field for a vocation.

TEACHING SCIENCE FOR MODIFYING BEHAVIOR

There seems to be a reasonable agreement among those concerned with formulating the general goals toward which education should be directed, that it should function to modify the behavior patterns of the individual in such a way as to make his adjustment to the problems of living more effective and more satisfying. The recent trends of objectives in science teaching all seem to be directed toward this more functional point of view.

If science teaching is to really become a useful agency through which young people may be helped to solve their adjustment problems, this point of view, and the methods by means of which it may be achieved, must become a part of the day to day work in the classroom. It must permeate the thinking of the teacher as plans for lessons are prepared otherwise it becomes only a set of paper goals.

It is encouraging to see that in some places beginnings have been made in formulating courses of study on this basis. In its Preliminary Report, the Science Committee[13] of the Colorado State Course of Study For Secondary Schools proposed objectives for science teaching in terms of human adjustment as follows:

> Science then has two general objectives to realize if it is to contribute to the education of boys and girls in the secondary school.
>
> (1) Science should develop functional understandings that will help the individual make satisfying
>   (a) Adjustments to self-personal adjustments
>   (b) Adjustments to the immediate social group
>   (c) Adjustments to the community
>   (d) Adjustments to economic life
> (2) Science should develop the individual's ability to consciously use the problem solving method
>   (a) This includes the development of scientific attitudes
>   (b) The ability to use the skills involved in problem solving

The above areas of adjustment are very broad and are not meaningful for the guidance of the teacher in his day to day planning unless they are analyzed into more specific and more immediate goals of instruction. Such analyses would, of necessity, be tentative and constantly shifting because of the changes that are constantly taking place in the environment of the individual. Pieper[14] has proposed a useful list of criteria that may be applied in the selection of adjustments for use as experiences in the learning of science:

> When in each case all other things are considered equal, criteria should be applied that will assure that those adjustments selected are:
>
> (1) Universal in their application to life needs
> (2) In accord with the findings of science
> (3) In harmony with the best interests of society
> (4) Crucial in individual or social life
> (5) Conducive to the desire to make further worthwhile adjustments
> (6) Of the proper order of difficulty

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[13] Recommendations for Improvement of Learning in Science. Preliminary Report of the Science Committee of the Colorado State Course of Study for Secondary Schools. J. Darrell Barnard, Chairman (Mimeographed).

[14] Pieper, Charles J., "A Program for Teaching Science," Thirty-First Yearbook of the National Society for the Study of Education. Distributed by the University of Chicago Press, Chicago, 1932.

(7) Highly satisfactory to the individual without giving harm to others or to himself
(8) Desired by the pupils
(9) Identifiable in their attainment
(10) Essential to the making of other desirable adjustments

A Further Consideration of Objectives for Teaching Science

The role of content in science learning. The trend is definitely in the direction of utilizing science content as a means to the end of better adjustment, rather than as an end in itself. The emphasis placed on functional facts, functional concepts, and functional principles, would seem to indicate that science instruction on all levels must be directed toward the learning of the larger principles of science rather than the learning of isolated facts. Several important and significant research studies to determine the important science principles for different levels of instruction have been made, among these the work of Robertson,[15] Pruitt,[16] Winters,[17] Martin,[18] and Wise[19] should be mentioned.

The importance of functional principles for the adjustment of individuals is not remote, but becomes very real and immediate, when one considers the focal points in the everyday experience of boys and girls where science situations and their social implications merge to create real problems. A few of these will illustrate the point. Each of the following, and probably others, are general areas of human experience where young people meet the adjustment problems of living which they must solve. Each of these areas would need to be analyzed in great detail to ascertain exactly what principles of science will function to meet the adjustment needs of young people.

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[15] Robertson, Martin L., "A Basis for the Selection of Course Content in Elementary Science," Ph.D. Thesis, University of Michigan, 1933.

[16] Pruitt, Clarence M., "An Analysis, Evaluation, and Synthesis of Subject-Matter Concepts and Generalizations in Chemistry," Ph.D. Thesis, Teachers College, Columbia University, 1935.

[17] Winters, Elwood J., "The Determination of the Meaning Which Students of Science at Different Grade Levels Associate with Selected Scientific Concepts," Ph.D. Thesis, New York University, 1939.

[18] Martin, Edgar W., "A Determination of Principles of Biological Science Important for General Education." Ph.D. Thesis, University of Michigan, 1944.

[19] Wise, Harold E., "A Determination of the Relative Importance of Principles of Physical Science for General Education," Ph.D. Thesis, University of Michigan, 1941.

Health.

There is no more important aspect of present day living than good health. A health problem may be an immediately personal one to an individual, as in the case of diet, or it may be a community concern, such as sewage disposal or a pure water supply. Again, a health problem might be national in scope, as in the case of an adequate health bill to be passed by the Congress. Regardless of the scope of these health problems we find the science principles inextricably bound up with social situations.

Safety.

The problems of safety with respect to home, school, community, or nation are of extreme importance. It is believed that proper education can go a long way toward lowering the number of accidents and accidental deaths in this country. Science can contribute much to this education, for many of the causes of accidents have implications for the principles of science, such as the prevention of fires, safe driving, electric shock, and drownings. Thus safety, in all its many aspects becomes another focal point in contemporary living where the advances of science have led to social effects which young people must understand and to which they must adjust.

Conservation.

This problem is world-wide in its scope. During the past few years it has been brought forcibly to the front by the recurrence of devastating forest fires, floods, and dust storms in many parts of the world. Indeed, the problem has become so pressing that many of our leading thinkers in the field are beginning to predict dire consequences predicated on the belief that food supplies, for the future of mankind, are greatly endangered. If we ever hope to achieve really widespread concern for, and action on, the problems of conservation, the topic must become a more intimate part of education in our schools. At present we are doing little with it in science, and yet, the basic reasons and needs for conservation find their causes in the principles and meanings of science, such as the origin and structure of soils, erosion and its control, forests and floods, conservation of water power, irrigation, conservation of national resources, and the agencies of conservation. Each of these has science-social significance for the individual, the community, and the nation. Thus, conservation becomes a problem in modern living to which many people must adjust. Complete and effective adjustment can come about onlv as the individual has built meaning for the specific science principles in their social settings.

Consumership.

Every individual is a potential consumer of goods, materials, and services and should have, as a result of his education, a stock of functional science principles, concepts, and attitudes to bring to bear on the problems which will confront him in this important area of living. In this area, perhaps more than in any other, we find an involved interplay between science principles and their social implications. Most goods and materials at some point in their production, processing, or distribution, have had to do with some phase of science. In a bulletin entitled "The Place of Science in the Education of the Consumer,"[20] published by The Consumer Education Study the following are suggested as contributions which science teaching can make in this area:

(1) *To help students to use science in making wiser decisions about purchases.*

. . . With respect to actual over-the-counter purchasing, science can help make analyses and comparisons of such factors as *usefulness,* as in drug store vitamins; *lasting time,* as in an electric motor or bed sheet; *health values,* as in a drug; *safety,* as in an insecticide.

(2) *To help students to employ science in the effective use or operation of goods and services.*

The wise purchase of an automobile is important, but not so important as its effective and safe use over a period of years. . . . It can also teach him to apply numerous scientific principles to the preservation and preparation of foods, to the care and maintenance of clothing, and to the management of his home.

(3) *To help students to use science in improving their own production for home use.*

. . . Science can contribute to improved production through wider use of more productive varieties of plants and animals such as hybrid corn and pure-bred cows, through soil maintenance and improvement; through the conversion of wastes into useful materials.

(4) *To aid pupils in the wider applications of the methods of science to the solving of consumer problems.*

Consumer problems offer excellent opportunity for the use of critical thinking. . . . Experimental tests of consumer goods provide opportunities for realistic application of scientific techniques.

These four illustrations have been dealt with in some detail to show what is meant by areas of adjustment and how principles of science may become functional in the solution of problems confronting young people. These are only representative of many areas of human experience. Others which might have been expanded are *vocation, recreation, interdependence,* etc. . . .

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[20] "The Place of Science in the Education of the Consumer" Consumer Education Study, 1201 Sixteenth St. N.W., Washington, 1945.

If functional science principles are to be sought as worthwhile outcomes of instruction, then they must be more than merely stated goals or objectives. They must find their way into the day to day classroom experiences of young people.

The role of appreciation in science learning. Wheeler and Perkins[21] in their book *Principles of Mental Development* say, "The intelligence which education is calculated to develop will not grow when uprooted from the background of feeling from which it springs."

Adjustments to the situations encountered in modern living are not made on the basis of cold factual applications alone but also with feeling and emotion. Each adjustment situation is a complex of feelings, attitudes, and understandings. It would seem then, that a background of appreciations which are peculiar to science should become one of the desired outcomes of instruction in this area.

The emergence of science as a body of tested laws and principles has been intimately bound up with stories of romance, privation, and adventure. These should become a portion of the cultural heritage of every boy and girl. In modern living young people are called upon to use the products of science and inventions. Their intelligent adjustment to the problems growing out of these uses will depend, in part, upon the extent to which they appreciate the background from which the science principles come, such as the story of Louis Pasteur and his services to humanity; the persecutions of Galileo in the name of science; Edison and the discovery of the electric lamp.

Not only is the development of science knowledge filled with fascinating historical and biographical incidents, but also with many appreciations which give depth and perspective to living, and which may serve in the development of character. The tremendousness of space; the vastness of the sweep of geologic time; the law and order of the universe; the potentialities of the energy of the atom; confidence in the method of sicence: these and others which might be listed give ample justification for the inclusion of *appreciations* as one of the major goals of science teaching.

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[21] Wheeler and Perkins, *Principles of Mental Development* Chapter I, Thomas Y. Crowell, St. Louis, 1936.

The role of attitudes in science learning. Science teaching has long concerned itself chiefly with the mastery of laws, facts, and principles to the neglect of certain of the less tangible, but none the less desirable, outcomes, such as attitudes of mind. There has been a belief of long standing that if the laws, facts, and principles were mastered, the growth in scientific attitudes would be added on to the learner concomitantly. Nothing could be further from the truth than this assumption.

During the last few years science teachers, as well as teachers in other areas, have become aware of the fact that if attitudes are to result from instruction, they must be sought just as deliberately in the classroom as we have sought, in the past, for the mastery of laws and principles. Attitudes have been defined in many ways. One definition which has had wide acceptance is a mental-motor set of the individual which is characterized by predisposition toward objects, persons, or events, and a tendency to act. Thus, it would seem that there is hardly a science situation to which young people must adjust that does not in one way or another involve an attitude of mind. It would further seem true that attitudes are eminently essential in the satisfaction that must derive from the complete adjustment to situations. If the assumption that they are worthy as outcomes of science be accepted, then teaching from day to day should be so ordered that it will provide the maximum of practice in many desirable attitudes.

While it is probably true that science is better fitted by the very nature of its materials and methods to foster the development of certain attitudes, it is equally as true that other subjects can make significant contributions to this outcome. Later in this book a list of attitudes to which science can contribute will be given.

The role of problem solving in science learning. The methods used by the scientist in his efforts to discover truth have been regarded for a long time as effective in the solution of non-science problems. The methods have been studied and analyzed by many writers, and there seems to be a considerable agreement on the elements which constitute it. Science in the school curriculum, because of its peculiar materials and opportunities, is a promising area for developing the skills and habits of problem solving in young people.

Problem-solving abilities, as desirable outcomes of science instruction, are not new. One may read in the preface of most any science textbook and in the objectives of many courses of study, the statement that problem-solving skills should result from the study of science. There is little evidence to show the degree to which science instruction in the past has achieved this goal. There is an increasing body of evidence which shows that under proper teaching, the habits and skills of problem solving may be achieved. If there has been failure in this in the past it has probably resulted from the fact that teachers have not been aware of problem-solving abilities as teaching goals, or because they have not been familiar with the techniques of organizing and presenting science materials which lead to the achievement of the goals of problem solving.

Training in the abilities of problem solving becomes more important when one considers the fact that most of the situations in present day living crop up in the pattern of a problem or perplexity. If, through learning experiences in school, the individual has learned how to identify, attack, and solve problems, it is reasonable to think that his adjustment to a given problem situation will be more effective than if he had not had the training.

There is still considerable difference of opinion concerning the extent to which skills and habits acquired in one context may be transferred to a new situation. There is some agreement on the point that when there are similar elements in the training situation and the new situation, a carry-over is more likely to occur. This would seem to point out that, as in the matter of developing attitudes, training in the techniques of problem solving should be a school-wide objective. With such a wide basis of experience an individual would have a better chance of solving a novel situation.

There is considerable evidence available to show that content, as now taught in science, is not particularly functional when new situations are presented where principles are to be applied. There is also another body of evidence which reveals that content as now taught is not retained for any length of time and that the curve of forgetting falls off very sharply after a lapse of a few months.

On the other hand Tyler has shown through his studies, that content learned in reference to the solution of problems, where problem-solving techniques have been actively used in the process, is, instead of being forgotten, actually augmented with the passing of time.

As noted earlier in the chapter, it is quite probable that science and technology will continue to influence our changing society for some time to come. While we have no way of predicting what the changes will be nor the kinds of adjustment problems they will create, we may reasonably assume that there will be problem situations to which individuals will have to adjust. Since we cannot teach specifically for these adjustments it seems that the best safeguard, which we can now provide, would be a method of attack which will enable young people, at least in some degree, to cope with these problems.

Problem-solving abilities, as major outcomes for science teaching, can be achieved only when they are sought as desired behavior changes in young people, and when the learning activities in the classroom are so set that pupils are given recurrent training in the skills involved. They must be taught for as vigorously as we now teach for the mastery of facts and principles. In a later chapter detailed attention will be given to the methods of achieving this outcome.

The role of interests in science learning. The part played by interest in learning has been dealt with at length by writers and investigators. It is of such importance as to claim a position as a major outcome in any area of learning. Teachers must be alert to keep the classroom experiences in day-to-day learning pitched to a high level of interest. For activity that is shot through with vital interest would seem to be more fruitful in producing lasting outcomes than those attended by routine drudgery.

The puzzle or problem situation seems to have wide appeal both to children and adults alike. People are challenged by a perplexity that demands some sort of solution—it seems to enlist interest inherently. Perhaps teachers could make more use of this natural interest and could stimulate learning more by using a problem approach to the presentation of content.

The science teacher has many devices not present in other areas for creating and sustaining interest: the natural desire of young people to experiment; the lure of science equipment such as microscopes and telescopes; the interest in taking things apart; the science club, and others. These will be discussed in detail later.

Interest has another aspect as an outcome of learning in science. Granted that the interest of day-to-day experiences is a vital force in effective learning, of far greater importance is the development of the long-time, abiding interests in science, those interests which may lead to vocational or avocational pursuits in the years ahead. Again, science is in a preferred position for there are a multiplicity of vocations open to young people in the field of science. Also, there are boundless opportunities for the development of lifelong hobbies in the area of science. The consequences of these aspects of interest are far reaching with respect to adjustment potentialities. The science teacher has a real obligation to see to it that both the vocational and avocational aspects of science have a prominent place as outcomes of instruction.

QUESTIONS AND EXERCISES

1. Compare the objectives for nature study and elementary science and write a critical summary of your findings.
2. Trace the changes that have taken place in the objectives for general science since its inception in the school curriculum.
3. Discuss the influence that children's interests should have in determining the objectives of science teaching.
4. What are the factors that have influenced the decline in enrollment in physics and chemistry over the past fifty years.
5. Discuss the influence that the growth characteristics of young people should play in determining the objectives for science teaching.
6. Objectives should be stated in such a way as to give some indication of content materials to be selected, methods to be used, and evaluation procedures. Make an analysis of as many sets of objectives for science teaching as you have available and select objectives that would meet the above criteria. Attempt to restate some objectives that do not conform to these criteria so that they will.

7. Make out two lists of objectives for science teaching. One list should be functional, in your judgment, and the other, list non-functional objectives.
8. Write a critical evaluation of the list of criteria proposed on pages 25 and 26 for the formulating of objectives.
9. Make a critical analysis of all the statements of objectives for elementary science found in this chapter. What conclusion can you reach on the basis of your study?
10. Repeat Exercise 9 for the statements of objectives for the junior high school.
11. Make a careful study in the original sources of all the studies to determine science principles mentioned in this Chapter. Compare them on the basis of each of the following:
    (1) Purpose
    (2) Technique
    (3) Findings
12. Discuss the problem of integrating such areas of human experience as health, conservation, safety, etc. in the science program, in contrast with the plan of offering separate courses in these topics.
13. Write a critical evaluation of the place of attitudes, interests, appreciations, and problem solving as objectives for science teaching.
14. Discuss the relative importance of the knowledge objective and those listed in exercise 13.
15. Make a list of objectives for science teaching on some selected level of instruction, that on the basis of your past experience and the study of this chapter appear to you to be worthy and defensible. Present these to the class for criticism.

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Chapter 3

PSYCHOLOGY OF SCIENCE TEACHING

What is teaching? To some it may seem trite to define teaching but it is none the less important to do so. Reeder[1] defines teaching as the "act of helping someone to learn, that is, of helping him to acquire knowledge, attitudes, ideals, habits, or some other type of learning which he did not previously possess." Teaching is the stimulus, and learning is the response. The function of the science teacher, therefore, is to provide the best stimuli in order that the best learning may take place.

Is teaching a science or an art? It is both. During the past several decades a large body of organized knowledge about teaching has been developed. Teaching already possesses many facts and principles and new facts and principles are being constantly added. Other things being equal, the more a teacher knows about the teaching process the more effective his teaching should be.

However, knowing the facts and principles of teaching does not in itself guarantee that good teaching will be done. A group of people may listen to and learn the facts of painting from a great artist but when they apply their brushes to a canvas not all of the paintings will be masterpieces. The great artist is a master of performance as well as a master of knowledge. So it is with teaching. It is one thing to know the facts and principles of teaching; it is another thing to apply this knowledge correctly. The final test of teaching is whether the pupil learns as much as his ability warrants he should learn.

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[1] Reeder, W. G., *A First Course in Education,* Macmillan Co., New York, 1943.

It makes for clarity in science teaching when the teacher understands the major goals of science teaching and the methods useful in reaching these goals. It is our purpose in this chapter to present: (1) a brief analysis of the goals in learning science from the standpoint of psychology; (2) the factors which condition learning; and (3) those psychological principles which may be useful to science teachers in developing methods for reaching the goals in learning.

Goals in Learning Science

The acquisition of a fund of functional understandings. Specific information about subjects or events is acquired by reactions to stimuli which affect our sense organs and which give rise to sensations of sound, odor, etc. The pupil sees a flower and states that it is a blue flower. He sees an exhausted can crushed by the atmosphere and states that air exerts pressure. Psychologists call this *perception.* In perception, the object or event is seen and interpreted in the light of experiences from the past.

Information may also be gained vicariously by reading or listening, if one has acquired the basic ideas needed to interpret what is read or heard.

Information lessons are of two kinds: either we observe something directly, as when we examine objects and specimens and watch demonstrations and experiments, or we translate somebody's message which comes to us as written or spoken words. "In either case" says LaRue,[2] "the first challenge of the lesson for information is to get its meanings: that is, to relate it to the mass of images, symbols, and feelings already in our heads; to *interpret* it. To perceive the outer world is to interpret sensations; a moving light in the sky turns out to be not a meteor but an airplane; that red on Johnny's finger is not blood from a cut, but a splotch of ink. The tadpole's tail disappears. What does that mean? What became of it? In the second type of information lesson we interpret symbols; words for the most part." What does it mean, for example, when the science textbook says "soil is formed by the forces of weathering and erosion?"

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[2] LaRue, D. W., *Educational Psychology,* Thomas Nelson and Sons, New York, 1939, p. 189.

Pupils have many concepts to form. In science we have such words as fruit, seed, atom, molecule, energy, work, mechanical advantage, and the like. If a word is to be a tool of thought it must mean something. The meaning of a word is a concept. Too frequently, for pupils, these concepts have but rough splotches of meaning whereas they should be as clear-cut as diamonds. Much of this is the result of too much verbalism or too much "definitionism." Scientific terms are learned and repeated without the pupils having the proper sensory experiences.

Two of the chief causes of pupil failures in science courses are lack of concrete experiences with objects and events and the prevalence of hazy concepts. Pupils have difficulty in understanding a sentence such as this: "Fruit is the matured seed vessel and its contents, together with such accessory or external parts of the inflorescence as seems to be integral with them." When a teacher exhibited a potted fern before her class and asked what it was, one pupil said it was a "pot of green feathers." This pupil needed a trip to a greenhouse.

How are concepts and generalizations formed? Pupils progress through levels of maturity. At each level they should participate in rich and varied learning experiences. Understandings needed in adult life begin their growth in the nursery. They grow and expand through continuing experience until the learner emerges into adult life.

Pupils react to stimulating objects and events. They apprehend objects through their senses, singly or collectively and appraise their significance for future behavior.

A concept may be simple or complex. A pupil's concept of a flower may, at first, be limited to the simpler aspects of size, shape and color. Later he may learn that a flower has sepals, petals, stamens, and pistils. Then his concept of "flower" may be still further enlarged as he learns that a flower produces sperms and eggs, and what the function of these parts are in the process of reproduction.

It is important that the concepts to be developed at any grade level be carefully defined by the teacher. Then the learning exercises and experiences should be provided that will stimulate the pupils to learn. This kind of planning and teaching will eliminate much dry verbalism. Sometimes pupils form a concept by taking the task as a problem in thinking and then solving it. Let us see by means of a concrete case, how a concept of this type may be formed. A student in a biology class is surprised when he hears his teacher speak of a pine cone, nuts, and watermelons as fruit. His curiosity is aroused. He asks, "What is a fruit?" He has formulated a problem. His teacher helps him to get facts by considering many samples of fruit, such as apples and berries, cherries and plums, nuts, oranges, and tomatoes. As the study proceeds, the student notes various differences and sees that the "build" of the fruit is unessential. He then perceives that there is a quality or characteristic which is common to all of them: a fruit is the part of the plant which carries the seed. He has generalized and built up in his mind a concept of "fruit." This is the inductive process. The pupil may now, if the occasion arises, use the concept deductively. Is a potato a fruit? He examines a potato and finds that it contains no seeds. It is simply a modified stem.

Concepts transcend in meaning any particular percept. A percept refers to a specific situation; the concept is general and universal in its scope and reference. Science teachers should guide their students in distinguishing intellectually two kinds of qualities or characteristics; those peculiar to each situation, and those which it possesses in common with others of its kind or class. When the common element in a number of experiences has been recognized and abstracted from the multitude of accidental qualities, a concept has been formed; generalization has taken place. The end product may be a principle, a definition, or even a scientific law. Experiences thus generalized into concepts make possible transfer of knowledge and adaptability to new situations.

Do concepts differ in difficulty? There are different levels of difficulty in concept building and the science teacher needs to be aware of them. Consider the field of chemistry. By the concept sulfur one may mean a yellowish substance which when combined with the element hydrogen yields a substance having the disagreeable odor of rotten eggs. This concept of sulfur may be built from simple sensory perception. On the other hand, the concept of sulfur may mean a certain number of electrons in orbits around a positive nucleus, or a set of energy levels defined as a part of a system which behaves according to the rules of quantum mechanics. This latter concept of sulfur gathers its meaning from special theories of science and is not understandable to a pupil on the basis of simple sensory experiencing. Therefore the latter concept of sulfur is much more difficult than the first one.

Consider also the science of physics. In the treatment of colors what is the concept "blue"? By the concept "blue" one thinks first of all of the immediately sensed color. But this is not all "blue" may mean. According to the theory of optics the concept "blue" means also a definite number, called the *wave length.* But a wave length is part of the system of electromagnetic propogations based upon the postulates of the electromagnetic theory.

Many other examples of science concepts could be drawn from the field of science. But these are sufficient to show that science concepts fall into two general groups; concepts which are gained through simple sensory perception and concepts which gain their meaning from theories proposed by the theoretical scientist who draws upon the full play of his imagination and upon investigations in the field of pure mathematics.

It should be clear to the science teacher that the second order of concepts are much more difficult to learn and to teach. Science courses become increasingly difficult to the learners to the extent that these more difficult science concepts are introduced.

The acquisition of a fund of appreciations. Because of the rapidly growing body of scientific knowledge, there is great danger that in our science teaching we may uproot this knowledge completely from the background of feeling and experience from which it has sprung. In so doing, pupils may lose some of the educational values such as appreciations, social sensitivity, and attitudes which by many educators are considered just as important as the mastery of facts and principles of science.

The emergence of science as an area of knowledge is intimately bound up with thrilling stories of privation, persecution, romance, and adventure; for example, the life and work of Louis Pasteur, the suffering of Galileo in the name of science, the persistence of Edison which led eventually to the invention of the incandescent lamp. Through the study of episodes in the history of science it is likely that boys and girls will gain a better appreciation of science and the role which scientists play in our complex society. Furthermore, boys and girls may also acquire a better understanding of the attitudes, emotions, and thinking which characterize the work of a scientist and a greater feeling of confidence in the scientific method. Science is also rich in possibilities for the development of appreciations which give breadth and perspective to life and character. It has been observed that narrow-mindedness and bigotry tend to diminish as people, through a study of science, learn to appreciate the vastness of space, the tremendous sweep of geologic time, and the orderliness in nature in which effects result from natural causes.

Students of science need to understand and appreciate the time and toil needed to attain the products of modern science. They need also to realize that scientific discoveries and inventions are cooperative achievements made possible because the scientific discoveries of many investigators are pyramided one upon another. Consider the radio tube as an example. It had its beginning in the diode invented by Thomas Edison. The diode was improved by Fleming. DeForest added a third element, the grid. Tied in with these developments one is led to think of the work of Faraday and his discovery of electromagnatic induction, Hertz and his discovery of electromagnetic waves, and Marconi and his discovery of wireless communication.

The acquisition of certain attitudes or mind-sets. Science educators have long recognized that scientific attitudes are among the most important outcomes which should result from science teaching. Although some educators have considered scientific attitudes as by-products or concomitant forms of learning there has been a persistent growing tendency to view these attitudes as equal to or superior to the knowledge objective of science instruction. Science teachers are becoming aware that if scientific attitudes are to develop from the study of science, they must be taught for directly and systematically in the same manner as we try to develop a mastery of the principles of science.

Science teachers should know and understand clearly what the scientific attitudes are. A person who is scientific:

1. Is curious about his environment.
2. Believes that every effect has a natural cause.
3. Is open-minded.
4. Is critical-minded.
5. Is determined not to believe in superstitions.
6. Is unwilling to accept as facts any statements not supported by convincing proof.
7. Is willing to change his beliefs upon presentation of new evidence.
8. Respects another's point of view.
9. Maintains such ideals as honesty, patience, persistence, fairness and thoroughness.

Success in developing scientific attitudes depends ultimately upon the teacher. And it is important that the science teacher keep always in mind that children form attitudes more from example than from abstract precepts. The teacher's intellectual honesty, willingness to admit error, listening to others' ideas, and dealing in an unbiased way with facts make a favorable and lasting impression upon pupils. The science teacher should live and act the part in order that a warm conviction will accompany his teaching. The cultivation of the right attitudes requires both emotional and intellectual appeal.

What can a science teacher do to cultivate scientific attitudes? The following procedures are suggested:

1. Preserve democratic procedures in the classroom. If a desirable rapport is to be maintained between teacher and pupil there must be freedom of expression and a free movement of emotional influence.
2. Suggest projects which give the pupils experience in problem solving. Suggest problems that require the collecting of evidence in advance of forming a conclusion.
3. Stress frequently the need for adequate data before arriving at a conclusion and that conclusions based on insufficient data should be accepted tentatively.

4. Pupils often have attitudes which are based upon error and misconception. Popular ignorance such as beliefs in superstitions, diet fads, astrology, patent medicines, self-doctoring and the like should be dealt with when the pupils reveal them. Naive attitudes, as pupils reveal them, may be selected for class discussion. For example, many children believe that handling a toad will cause warts on a person's hand. Questions like these may be raised by the teacher: What evidence is there that this belief is so? What kind of an experiment could be done to prove or disprove this belief? The goal of training is to develop an open mind and a critical point of view. Try to create the attitude that statements are not necessarily true because they appear in print or because they are uttered by some older person in the community. Misconceptions can be dealt with most effectively by creating attitudes that will serve as checks on accepting half-truths and superstitions.

Science teachers must be patient. The difficulty in changing naive attitudes is related to their intensity. The more highly emotionalized a pupil's attitude is, the greater the difficulty in changing it. Children's superstitious beliefs will diminish with age as well as with educational attainment.

A method of attack on problems (problem solving). It seems no longer defensible to assume that mere mastery of facts and concepts of science will suffice to meet the needs of the child. It is emphasized in modern practice that the experiences through which mastery and understanding are attained should contribute to growth in some of the educational values such as appreciations, social sensitivity, and skill in problem solving. With this new emphasis in education, the subject matter of science is not the end but the means to an end of providing experiences that will result in development in the child of careful and thorough habits of thinking. If this view is accepted it becomes exceedingly important that the science teacher be thoroughly familiar with the steps in the complete act of thought: (1) a perplexing situation; (2) definition of the problem; (3) collecting data relevant to the problem; (4) setting a hypothesis; and (5) testing the hypothesis.

Scientific method may be described from two points of view: (1) in terms of what one does and (2) in terms of one's attitudes or ways of thinking. Both must be taken together to get the true picture. When a pupil solves a problem he may use any or all of the following procedures:

Sense a problem.
Assemble data by experimentation and careful observation.
Organize and evaluate data.
Propose an explanation, or hypothesis.
Test a hypothesis by further investigation.
Discover basic truths.
Apply principles to specific cases.

Equally important and correlated with scientific method is the scientific attitude previously described. This includes:

Freedom from bias, prejudice and superstitions.
Open-mindedness
Critical-mindedness
Intellectual honesty
Belief in cause and effect
Objectivity
Willingness to change beliefs when new evidence is found.

Much time will be required for pupils to develop these methods and attitudes. Carefully selected experiences provided in the kindergarten to the end of general education will need to be accumulated to achieve our objectives.

Factors Which Condition Learning

A good teacher is aware of the psychological significance of classroom practices. A good teacher knows the conditions under which learning goes on economically and effectively. The following are factors which are involved in the learning process:

The psychological factor: motivation. Motivation is, in a very large degree, the very heart of the learning process. Interest is prerequisite to effort. Incentive, purpose, and drive set in motion the activities which result in learning. The science teacher should consistently devote much thought and energy to ways and means of developing and maintaining, interest and enthusiasm in students.

Motivation may be *intrinsic* or *extrinsic*. When the subject matter of science courses is made so meaningful to the student that the student is bound to his work by interest within activities themselves, the learning of science carries its own reward. Motivation, then, is intrinsic. The student engages in wholehearted, purposeful activity. This is the ideal in teaching. But rare, indeed, is the teacher who can maintain the ideal situation in which learning for its own reward is the motivating force.

A pupil's behavior is governed by his own individual purposes. Each pupil in a classroom may react differently to the effort of his teacher to stimulate his learning. If all the pupils in a class are working it does not mean that they all have the same incentive.

It would seem that the teachers responsibility is to weave into a meaningful pattern every influence that will motivate the pupil to exert maximum learning effort. The following are some of the more common incentives that seem to produce increased interest and application.

Keeping the pupils informed of their results. Data from experimental psychology show that knowledge of his progress serves as an incentive to the learner. Tests should be given often enough to reveal to the pupils the progress they are making.

Davis[3] recommends that the following principles be observed in informing pupils of progress:

(1) *Test results are more effective when they reveal the learner's performance analytically as well as compositely.* Compressing the results of a test into a single score or mark has some value. But it is more stimulating if the learner knows the parts of the subject matter in which he is proficient and those in which he has further opportunity to improve. The results are even more meaningful if his performance is analyzed by test items in detail. The learner also benefits if his tests are analyzed with reference to the types of ability demonstrated. Knowledge of his achievement will be more significant, for example, if he knows that although his mastery of specific facts is inadequate, his treatment of major concepts involving reasoning is of good quality.

(2) *The pupil should have had opportunity to review previous tests before taking additional ones.* Failure to score tests and return them promptly conveys the impression that they are not given in the interests of the learner. It also makes it possible for errors to persist throughout several testing periods and affords the pupil an inadequate basis for correcting specific points of error or omission.

(3) *Test results are more effective when they reveal performance in terms of individual as well as group progress.* In many cases a pupil makes

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[3] Davis, R. A., *Educational Psychology,* McGraw-Hill Book Company, New York, 1948, pp. 317–318.

improvement that is conspicuous in terms of his individual ability and preparation. Superiority in a special ability may deserve mention in order to inform him that he has some basis for prestige. His improvement may suggest that he has made actual gain in certain abilities in which he was deficient, even though his total score still places him in approximately the same class rank. He may do exceptionally well in some aspect of a test but as a slow learner be unable to achieve the same amount of performance during a test as other pupils. But if he makes any noteworthy gain over his previous record, it should be recognized. Recognition of one success in learning may overcome the effect of several instances of failure.

(4) *Frequent testing is more beneficial to a slow than to a rapid learner.* Since slow learners have less insight into their abilities than able learners, they depend to a greater extent than their abler classmates upon test results for knowledge of their performance and need frequent checks of their progress.

Rewards and punishment. Rewards are powerful incentives but they must be used cautiously and sparingly. Most educators believe that the satisfaction which comes from seeing a task well done is the best reward; whereas failure due to lack of effort carries with it its own natural form of punishment. The effect of both punishment and reward depends entirely on what they cause the pupil to do in the situation. The problem is always to bring about the behavior desired. This is another reason why teaching is an art and requires experience and patience.

Praise and blame. Some investigations indicate that praise is a more effective incentive than blame or reproof. It is also established that praise and blame may have similar effects. Both may spur pupils to greater effort. Both when improperly used may have an adverse effect.

A good teacher strives to understand each individual. He also observes the effect which praising or reproving has on the learner. In the last analysis the effects of praise and blame depend upon the total situation; the personality of the learner, the personality of the teacher, the presence of other pupils and their reactions, and the nature and difficulty of the learning task. Pupils who are immature, sensitive, or timid do not respond favorably to reproof. Most bright and well adjusted pupils seem to recover readily from blame.

Rivalry. Some teachers encourage rivalry between individuals in a class and rivalry between groups. Rivalry is a powerful incentive but it is a dangerous form of motivation in that it tends to breed resentment and jealousies. Self-rivalry, in which the teacher encourages the pupils to compete with their own past records is a valuable type of motivation.

The physiological factor. It has been stated that knowledge is based on sense perception, and that sense perception is the foundation of all higher forms of knowledge. Learning, therefore, is dependent on the conditions of the senses and the general tone of the individual.

Defective sense organs retard learning. Investigation shows that visual defects are prevalent to the extent of thirty per cent in secondary schools. Defects of seeing are sometimes passed unnoticed for a long period of time. These defects may cause headaches, nausea, dizziness, and disinclination to study.

The environmental factor. Atmospheric and other conditions in the schoolroom influence learning. The best atmospheric conditions are 68° F., 50 per cent relative humidity, and 45 cubic feet outside air per person a minute.

The psychological "atmosphere" (environment) has been shown to be more important, in some ways, than physical conditions in the schoolroom. A pupil's work may rise or fall because of the partner or associates he has in the laboratory.

Principles of Learning

The work of scientists is directed toward reducing facts to laws. This effort has also guided psychologists who are attempting to discover the conditions under which learning may take place best. During recent years hundreds of experiments on learning have been performed and reported in educational literature. Yet the laws of learning are still in the process of being formulated and they must be considered only as working principles and not the last word.

Then too there are so-called schools of thought in psychology. One hears about gestalt psychology, behaviorism, purposive psychology, connectionism, and others. This is another indication that psychology is as yet a young science which has not yet attained the stature of the natural sciences such as physics and chemistry.

Let us now direct our attention to those psychological principles which are presumed to state the fundamental conditions under which learning takes place. Although their has been much criticism and controversy about certain aspects of these laws, they nevertheless have had a profound effect upon procedures and practices in the schools of this country.

Law of readiness. This law was formulated by Edward L. Thorndike in 1913. It may be stated as follows: "When a bond is ready to act, to act gives satisfaction; and not to act gives annoyance. When a bond which is not ready to act is made to act annoyance is caused." According to this law the pupil must be ready to learn before he can learn—at least all that he should. The school environment and methods of teaching must be appropriate; the health and emotional tone of the learner must be good; and the learning tasks must be satisfying to him. When a pupil is getting ready for his science hour, his state of mind is perhaps the most important factor in determining his progress. Probably the most important problem a teacher has to face is that of securing a favorable attitude on the part of the pupils.

It is important that students of science get the right start. At the beginning of a science course the teacher should assign work which is within the range and grasp of the pupils and then lead gradually to more difficult work. If children are to get the most out of their school work they must have a favorable mind-set toward the teacher, the school, and the tasks assigned them.

Law of exercise. The law of exercise may be stated as follows: Other things being equal "exercise strengthens, and lack of exercise, weakens the bond between situation and response." That "practice makes perfect" is the popular version of this principle.

Two corollaries of the law of exercise are sometimes recognized. The first of these is called the *law of frequency*. The principle is that "learning is proportional to the frequency with which the learning factors are made operative."

The second corollary is called the *law of receney.* The generalization is that "other things being equal, whatever it is that makes for learning is more effective when recent."

There is considerable doubt as to the complete validity of the law of exercise and its corollaries. It is well established that sheer repetition does not necessarily result in greater learning. Practice makes for continued improvement if and when attention and observation go along with the practice. Practice must be of the proper kind and amount. Only intelligent practice makes perfect.

Law of effect. This law may be briefly stated as follows: "Satisfying results strengthen, and discomfort weakens, the bond between situations and response." In a man (and lower animals) profitless acts gradually become eliminated. Here again it must be mentioned that this principle also has been severely criticized by both behaviorists and gestaltists. It seems that people may remember experiences which are painful to remember and this condition is not adequately explained in the law of effect.

The psychological principles of readiness, exercise, and effect indicate that there is a close relationship between interest, attention, and effort. The teacher must stimulate interest. The pupil must be prepared for the work he is to undertake. The pupil must be in a state of readiness to act along desirable lines. When the pupils are in a state of readiness to act and the act is accompanied by satisfaction, learning results and habits of thinking and acting are formed as a result of exercise and study.

QUESTIONS AND EXERCISES

1. Can you explain the following words: percept, concept and generalization?
2. How are concepts formed?
3. Why are concepts that are formed on the basis of simple sensory experience less difficult than those concepts which are based on scientific theory? Give an example of each kind of concept.
4. Make a list of appreciations that you feel should be developed in science courses.
5. Write a description of your conception of the scientific attitude.

6. What can a science teacher do to cultivate the scientific attitude?
7. Write a description of your conception of scientific method.
8. Do you think that a person who lacks the scientific attitude will likely use the scientific method? Does one who has a scientific attitude always use scientific method?
9. Why is motivation sometimes said to be the "heart of the learning process?"
10. Make a list of things a science teacher can do which will act as incentives to pupil learning.
11. Write a paragraph explaining the law of exercise. Do the same for the law of readiness and the law of effect. Plan a lesson or a unit in science and indicate how you have applied these laws.

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Chapter 4

THE SELECTION AND ORGANIZATION OF MATERIALS FOR TEACHING SCIENCE

There comes a time in the experience of everyone who aspires to be a teacher when he must face a classroom full of young people. After he has formulated a point of view, become familiar with the goals of science teaching, and familiarized himself with the psychology of learning in the field, he must finally select and organize materials which will form the learning experiences for the young people whom he will teach. It is the purpose of this chapter to present certain helps and guides for the teacher in this all-important aspect of teaching.

The selection and organization of content can be a very crucial factor in determining the end product attained in learning. Obviously the content selected will determine the functional facts, concepts, and principles which the pupils will carry away from the course. But what principles shall be selected from the array available? What factors should determine the selection? Should some factors be considered more than others? What criteria shall be applied? All of these questions must be answered if the selection of content is to play its proper role in the education of young people.

When the principles of science that will form the basis for learning experiences in the course have been selected, it becomes necessary to so order these that learning may be both efficient and effective. Upon the plan for organizing materials may depend, in part, the extent to which certain desired outcomes are achieved. This is especially true of those outcomes that are somewhat less tangible such as attitudes, interests, and the skills of problem solving.

These depend in a very real way upon the manner in which the selected content is ordered for learning.

In many instances teachers depend upon an outside agency such as a course of study or a text book for the selection and organization of the content for their science courses. Often they have no choice in the matter especially where courses of study are followed to the letter and where textbooks are adopted and handed to the teacher. However, even within such rigid confines as these, the teacher will have to select and organize to some degree. This is true because most science textbooks contain far more material than can be covered in a one year term.

SOME CONSIDERATIONS IN THE SELECTION OF CONTENT

Ideas about the function of content in learning have changed. It has been pointed out previously that in the early days of science teaching in America the learning of content was regarded as an end in itself. It was learned largely for the purpose of entrance to college and was of little value for those who did not use it as such. Later a utilitarian function for science developed in the period when the Academies flourished and dominated the teaching in the early High Schools. Then, beginning about 1870, and continuing down to about 1900, the domination of the colleges was again felt. Courses were diluted college courses and the emphasis was again on preparation for college.

With the expansion of the high schools early in this century the concept of learning science content for its utilitarian purpose again became dominant. This concept of the content for science courses has grown and enlarged steadily until today we regard content as functional. We think of it as the means to the end of better social adjustment rather than as an end in itself.

What is the nature of the content or knowledge outcome?

A careful analysis of recent statements of objectives for science teaching will show a considerable confusion of meaning as to terms. It is not uncommon to find such terms as fact, law, principle, interpretive generalization, concept, major generalization, and others being used without precise definition when discussing the content objective. Before any order can come from this chaos of words it is essential, first to select the terms that seem most useful in describing the content objective, and then hold to the exact meanings of these terms. For purposes of this discussion the three terms fact, concept, and principle will be used. By *fact* will be meant a thing known to be true or known to have happened. By *concept* will be meant a generalized notion, thought, or idea made up of partial meanings. Thus many of the words commonly used in science are really conceptual words such as fruit, seed, energy, bacteria, work, machine, etc. One's concept of something is what he knows or feels about a thing. By *principle* is meant a higher order of generalization or conceptualization. Thus a principle might be made up of several related concepts. By way of illustration,

(1) Facts of Science
    (a) Water ascends in the stem of a plant
    (b) The earth turns on its axis
    (c) Air occupies space
(2) Concepts of Science
    (a) The age of the earth is very great
    (b) Machine, fruit, seed, work, power
    (c) Space is vast
(3) Principles of science
    (a) Energy can be transformed from one form to another
    (b) Matter is made up of molecules which are in a constant state of motion

Some of the investigators and interpreters of science education as well as some psychologists regard these three–facts, concepts, and principles as forming a sort of hierarchy. That is facts go together to build concepts and concepts build together to form principles.

In connection with each of these aspects of the knowledge or content objective the idea of function is implicit. Each is to be construed as important as an outcome of instruction, only as it functions in the direction of modifying the behavior of the individual to the end of better adjustment.

Selecting content for the course in elementary science. In general two methods of attack have been used in selecting the content for courses in elementary science (1) selection in terms of the interests of children, (2) selection in terms of the concepts and the basic principles of science.

Many studies of the science interests of children have been made in an attempt to formulate valid guides for the selection of content. The reader is referred to the research literature in the field for the techniques and specific findings of these studies. Among those that have made a real contribution are the studies made by Mau,[1] Downing,[2] Trafton,[3] Finley,[4] Palmer,[5] and Zim.[6]

The *Thirty-first Yearbook* of the National Society for the Study of Education[7] proposed, among other things, that the program in science through grades one to twelve be directed toward developing meaning for a selected group of major generalizations or concepts of science. Craig[8] developed the technique and determined a group of these concepts. They were selected from a variety of sources and then validated in terms of children's questions, the judgments of educated laymen, and meanings obtained from the writings of pure scientists. A complete listing of these concepts may be found in the *Thirty-first Yearbook* of the National Society for the study of Education.[9] A few given here are typical.

(1) The sun is the original source of energy for the earth.
(2) The earth's position and relation to the sun and moon are of great importance to life on the earth.
(3) The earth has been developed as the result of the action of natural forces.

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[1] Mau, Laura M., "Some Experiments with Regard to the Relative Interest of Children in Physical and Biological Nature Materials in Kindergarten and Primary Grades." *Nature Study Review,* 1912.

[2] Downing, Eliott R., "Children's Interests In Nature Materials." *Nature Study Review,* 1912.

[3] Trafton, G. H. "Children's Interests in Nature Materials." *Nature Study Review,* September, 1913.

[4] Finley, C. W., "Some Studies of Children's Interests In Science Materials." *School Science and Mathematics,* January, 1921.

[5] Palmer, E. L., "How to Meet Some of Children's Nature Interests." *Nature Study Review,* January, February, 1922.

[6] Zim, Herbert S., "Science Interests and Activities of Adolescents." Teachers College, Columbia University, New York, 1940.

[7] *Op. cit.*

[8] Craig, Gerald S., "Certain Techniques Used in Developing a Course of Study in Science for the Horace Mann Elementary School, *Contributions to Education No. 276,* Bureau of Publications, Teachers College, Columbia University, New York, 1927.

[9] *Op. cit.*

(4) All life has evolved from simple forms.
(5) Man has modified plant and animal forms through a knowledge of methods found in nature.
(6) There is very great variety and range in the size, structure and habits of organisms.
(7) There are fewer than 100 elements.
(8) All matter is probably electrical in structure.
(9) Man's conception of truth changes.
(10) There is a cause for every effect.

The pioneer work in the objective determination of functional principles of science was done by Downing[10] and a group of his associates. In this series of studies a varied array of magazines, newspaper articles, and other sources were analyzed to find the science principles needed for understanding of the articles. From the several studies, a composite list of fifteen principles of chemistry, fifty principles of physics, and seventeen principles of biology, were obtained. On the assumption that these principles were functional in the daily lives of people, it was proposed to make them the basis of courses in the three specialized sciences. The list of principles is too long to reproduce here. The reader is referred to Downing's[11] book where they are listed in detail. A few examples are listed below:

1. Principles of chemistry
   (a) The molecules of nearly all substances are composed of atoms of relatively few elements which in chemical change, separate, and recombine so as to produce new substances with different properties.
   (b) The rate of chemical change is increased by the presence of a catalyzer, by increase in the surface exposed by the reacting substances, by increased temperature, and at times by light.
   (c) Energy can be neither created nor destroyed; it may be transformed from one sort to another.
2. Principles of physics
   (a) The law of the lever—the power times the power arm equals the weight times the weight arm.
   (b) Solids are liquefied and liqiuds made into gases by heat, and the amount of heat used in the process is specific for each substance but equals that given off in the reverse process.

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[10] Downing, Eliott R., *An Introduction To The Teaching of Science.* The University of Chicago Press, Chicago, 1934.
[11] *Ibid.*

  - (c) The intensity of illumination decreases as the square of the distance from the source.
3. Principles of biology
  - (a) Man must protect those plants and animals which he has pampered by domestication by (1) cutting off the food supply of their enemies, (2) preventing the reproduction of those enemies.
  - (b) Characters are usually inherited as such and are determined by genes carried in the chromosomes.
  - (c) The cell is the structural and physiological unit in all organisms.

Robertson[12] using a somewhat more elaborate technique than had been previously used, selected 243 principles of science. These were rated by a jury of authorities in the teaching of elementary science and reduced to 113. These principles were then evaluated and weighted in terms of several previous investigations. The principles were finally checked in terms of a large number of children's questions. A few of the principles selected at random from the study will serve to show the type.

(1) Food, oxygen, certain optimum conditions of temperature, moisture, and light, are essential to the life of most living things.
(2) Species not fitted to the conditions about them will not thrive and finally will become extinct.
(3) When a liquid is changed to a gas, heat is absorbed; when a gas is condensed to a liquid, heat is liberated.
(4) The material forming one or more substances without ceasing to exist may be changed into one or more new and measurably different substances.
(5) The environment acts upon living things, and living things upon the environment.

Thus far attention has been directed toward the selection of content for elementary science in terms of the basic concepts and principles. It is true that most of the studies cited have taken children's interests into consideration in evaluating the principles that were selected. If a trend in the selection of content for elementary science in recent years may be discerned it would seem to be in the direction of giving increased emphasis to the needs of children.

The many available studies of child development and child behavior have pointed the way to a clearer understanding of the growth patterns of children as well as to their needs. These needs may be classified as intellectual, motor, and social. Any content selected for the elementary science program should provide well for these types of needs on every level.

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[12] Robertson, Martin L., "A Basis for the Selection of Course Content in Elementary Science." Ph.D. Thesis University of Michigan, 1933.

Along with this trend there is a growing tendency to view the growth and development of the child as a whole organism and to see science as only one facet of this development. This demands that the science program, and its content, be planned as an integral part of the whole program and not as a separate entity. The studies of Haupt,[13] West,[14] Hill,[15] Williams,[16] and others have given ample evidence in the science field to corroborate this point of view.

The following list of characteristics have been taken from several studies and lists of growth characteristics for children at the elementary school level. While it is beyond the scope of this book to give a complete listing of growth traits for every grade level, the following will be suggestive of the types of needs which must influence the selection of content for elementary science.

Children in the elementary school:

(1) are extremely active and most any form of mental or physical activity interests them;
(2) are interested in people and things that are close at hand such as, animals, trains, the fireman, the postman, etc.;
(3) are interested in goals that may be attained quickly;
(4) generally make interpretations in terms of their own immediate experiences;
(5) like to play "make believe";
(6) like to make discoveries for themselves;
(7) enjoy books about animals, birds, nature, and in general books that have a "fairy tale" theme;
(8) like to express themselves through drawing and painting;

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[13] Haupt, George W., "Experimental Application of a Philosophy of Science Teaching In An Elementary School," Bureau of Publications, Teachers College, Columbia University, New York, 1935.

[14] West, Joe Young, "A Technique for Appraising Certain Observable Behavior of Children in Science in Elementary Schools," Bureau of Publication, Teachers College, Columbia University, New York, 1937.

[15] Hill, Katherine E., "Children's Contributions in Science Discussions," Bureau of Publications, Teachers College, Columbia University, New York, 1947.

[16] Williams, Alice M., "Children's Choices in Science Books," Bureau of Publication, Teachers College, Columbia University, New York, 1939.

(9) are interested in things that move; toys, trains, buses, airplanes, etc.;
(10) can engage in a variety of problem-solving activities at their own level;
(11) are motivated by collecting and ownership;
(12) are interested in radio and the comics;

Principles for guidance in the selection of content for science in the elementary school.

(1) Content should be selected in terms of the broad concepts and principles of science.
(2) Content should be selected in terms of the specific and general adjustment needs of children.
(3) Content should be selected in terms of the interests of children.
(4) Content should be selected in terms of the growth, level, or patterns of children.
(5) Content should be selected in terms of the level of difficulty for children.

Selecting content for the course in general science.

Investigations directed at the selection of content:

A considerable list of research studies directed toward different aspects of the content for the course in junior high-school science has grown up over the years. These studies generally fall in the following categories, (1) studies of children's interests, (2) analysis of textbooks and courses of study, (3) studies of life activities, (4) studies of the literature, (5) studies of science in the public press, and (6) studies of vocabulary. The volume of these studies make it impracticable here to review more than a few of them to delineate trends. For the methods and findings of the earlier studies the reader is referred to the *Thirty-First Yearbook* of the National Society for the Study of Education,[17] and to Curtis, The Third Digest of Investigations in the Teaching of Science,[18] a report by David J. Blick,[19] and three issues of the Review of Educational Research.[20] For those readers interested in the early studies relating to the selection of content for junior high school science the following are mentioned as typical: Webb,[21] Howe,[22] Weckel,[23] Meier,[24] Pollock,[25] Curtis,[26] Curtis,[27] Downing,[28] Fitzpatrick,[29] Searle,[30] Finley,[31] Nettles,[32] and Heiss.[33]

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[17] *Op. cit.*

[18] Curtis, F. D., *Third Digest of Investigations in the Teaching of Science,* The Blakiston Co., Philadelphia, 1939.

[19] Blick, David J., *Digest of Investigations in the Teaching of Science 1937–1943,* University of Connecticut, Connecticut, 1944 (Mimeographed).

[20] *Review of Educational Research,* 12 (Oct. 1942) Nos. 4 and 15 (Oct. 1945) No. 4.

Among the more recent studies of the content selected by textbook writers for inclusion in the science program for the junior high school the following should be mentioned: Petit,[34] Sisson,[35] Gervers,[36] Graham,[37] Hurd,[38] Simmons,[39] Hunter and Parker.[40]

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[21] Webb, Hanor A., "A Quantitative Analysis of General Science Texts," In, *General Science Instruction In the Grades.* Contribution to Education, No. 4, George Peabody College For Teachers, Nashville, 1921.

[22] Howe, C. M., "Can and Should General Science Be Standardized?" *School Science and Mathematics,* XIX, 1919, 248–255.

[23] Weckel, Ada L., "Are Any Principles of Organization of General Science Evidenced By The Present Textbooks In the Subject?" *School Science and Mathematics,* XXII, Jan. 1922.

[24] Meier, Lois, "Health Material In Science Textbooks." Bureau of Publications, Teachers College, Columbia University, New York, 1927.

[25] Pollock, C. A. "Childrens' Interests As a Basis of What To Teach In General Science," *Educational Research Bulletin,* (Ohio State University) 3: 3–6, Jan. 1924.

[26] Curtis, F. D., *Investigations of Vocabulary in Textbooks of Science for Secondary Schools.* Ginn & Co., Boston, 1938.

[27] Curtis, F. D., *A Synthesis and Evaluation of Subject-Matter Topics in General Science.* Ginn and Co., Boston, 1929.

[28] Downing, Elliot R., "Children's Interest In Nature Materials." *The Nature Study Review,* VIII, pp. 334–338, Dec. 1912.

[29] Fitzpatrick, F. L., *Science Interests,* Bureau of Publications, Teachers College, Columbia University, New York, 1936.

[30] Searle, O. H., "A Study of Science Articles in Magazines," *School Science and Mathematics,* XXVI, 389–396, 1926.

[31] Finley, Charles W., "Some Studies of Children's Interests In Science Materials." *School Science and Mathematics,* XXI, Jan. 1921.

[32] Nettles, C. H., "Science Interests of Junior High School Pupils," *Science Education,* XV: 219–255.

[33] Heiss, Elwood D., "An Investigation of Content and Mastery of General Science Courses," Published by the author, 1932.

[34] Petit, Donald D., "The Content of Junior High School Science," *School Science and Mathematics* XL, (Oct. 1940) and (Nov. 1940).

[35] Sisson, Jerome C., "Selecting Functional Subject Matter for a General Science Course," *Science Education,* XXVII, Feb. 1943.

[36] Gervers, Virginia, "Materials and Methods Found In General Science Textbooks Published since 1910." *Science Education,* XXIV, Apr. 1940.

[37] Graham, Charles C., "Some Data Pertinent To Textbooks of General Science." *Science Education* XXV Jan. and Feb. 1941.

[38] Hurd, Jerome R., "An Evaluation of Certain General Science Textbooks on the Basis of their Contribution to Health Education." *Science Education* XXV, Nov. 1941.

[39] Simmons, Maitland P., "Changing Conceptions of Topic Illustrations in General Science Textbooks," *Journal of Experimental Education* V, June 1937.

[40] Hunter, George W., and Parker, Alice L., "The Subject Matter of General Science." *School Science and Mathematics* XLII, Dec. 1942.

Certain of these studies report a considerable variation in the content selected for a given grade level but a fairly general agreement for the total content over the entire junior high school program.

Novack[41] studied the science found in the public press. Of fifteen major topics treated he found the greatest amount of space devoted to health, medicine, transportation, and communication. Ruffner[42] found in his studies that the science interests of ninth grade pupils were sufficiently permanent to be used for determining areas to be taught. Matteson and Kambly[43] found that the items, in a test of 199 items, were not learned below the seventh grade. They believed that such a study might indicate types of items needed for study on the junior high school level.

These studies are without doubt important in indicating guides to the selection of content for the course in junior high school science. However, the emphasis on studies such as those mentioned, seems greatly out of proportion to those directed at the fundamental needs of young people for the solution of adjustment problems. It would also seem that we need many more studies devoted to the adjustment of content to the varying maturity levels of young people rather than so many aimed at textbook analysis and the agreement of courses of study.

Some of the recent studies have indicated a trend toward the adjustment of science content in the junior high school to the maturity and abilities of pupils. Among these studies should be mentioned those of Bailey, Smith, Winters, Curtis, Shores, and Swenson. These investigators agree generally on the point that many of the science concepts and the accompanying vocabulary burden are too difficult for the maturity level of the junior high school.

The role of the textbook in the determination of science content. There can be little doubt but that research studies such as those cited above have had, and will continue to have marked influence on the selection of content for junior high-school science. It is however, equally true that this influence reaches the teacher of general science not directly, but through the medium of the course of study and the textbook. The textbook is, in the final analysis, the most influential factor in determining what is to be taught in any science. It would seem therefore that those who are given the problem of selecting textbooks should regard it as a very real obligation and should attempt to make the selection as objective as possible.

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[41] Novack, Benjamin, "Science in the Newspaper." *Science Education,* XXVI (October 1942) 138–143.

[42] Ruffner, Frances E., Interests of Ninth-Grade Students In General Science." *Science Education,* XXIV (January 1940), 23–29.

[43] Mateson, Harvey D., and Kambly, Paul E., "Knowledge of Science Possessed by Pupils Entering Seventh Grade," *School Science and Mathematics,* XL, March 1940, 244–247.

The fact that textbooks do wield such an influence in determining the science content taught must be viewed objectively. There are many who condemn the textbook, and no doubt its improper use may become a detriment to learning and to interest. On the other hand, many young teachers would feel inadequate to the task of selecting science content and would find themselves quite lost if confronted with it. Textbooks have long been the foundation of the American high school and probably will so continue. Thus the problem should be dealt with realistically and as objectively as possible.

In the selection of a textbook there are certain factors that should be taken into account. The following list has been used over a long period and has proven effective. The influence that the various factors should have is, to some degree, a matter of opinion and will vary from place to place.

Factors to be considered in the selection of a science textbook:

(1) The selection and organization of content.
(2) The psychological plan of development of topics.
(3) The standing of the authors.
(4) The teaching helps and supplementary materials given by the book.
(5) The quality and selection of illustrations.
(6) The difficulty of the book in terms of vocabulary.
(7) The appeal, for pupils, of the author's style.
(8) The mechanical makeup and durability of the book.

Selecting content for general science in terms of the adjustment needs of young people. The influences that have directed the selection of materials for general science in the past have been largely content centered. In more recent years a trend seems to have developed, to regard the pupil to be taught as more important than the subject matter; to regard content as one of the factors in the educational experience of young people rather than as the ultimate end of all instruction. As this concept has taken hold and developed there has been greater concern among curriculum workers to place more emphasis on the part that science can play in the adjustment of young people; on the social values of science; on the contributions that science can make to improved thinking, in the form of desirable attitudes and skills in problem solving.

As was true on the elementary levels, the studies made of behavior, interests, and growth characteristics, point the way toward utilizing other significant factors in the selection of content for junior high-school science. Just as the needs of children in the primary and intermediate grades differ from those of the pre-school child, so the needs of the junior high school pupil differ. Growth is a steady and ever widening process. From the available studies and lists the following characteristics of pupils at the junior high school levels have been suggested as typical. These may serve as guides to the building of a more detailed list to use as helps in selecting content that is more effective.

Characteristics of junior high school pupils;

(1) they are going through a period of rapid growth,
(2) their interests are centered in sports, teamwork, collecting, animals, adventure, romance, and mystery.
(3) they have a strong desire to excel,
(4) they like to explore and make discoveries for themselves,
(5) they seek group approval and often go to extremes of behavior to secure it,
(6) they have a strong desire and a keen interest to understand themselves,
(7) there is a desire for freedom balanced by the sense of a need for security and belonging,
(8) their play is self directed to a large degree and is, generally, well organized,
(9) there is the beginnings of wide interest in the group and in community concerns,
(10) there is a desire to achieve their full capacities,
(11) there is an accelerated development in motor skill and ability,
(12) there is a wider interest in reading,
(13) there is an awakening to, and interest in, ideals,
(14) there is a beginning interest in the vocational pursuits of adults.

Based on previous studies and lists of criteria and principles the *Forty-sixth Yearbook* of the National Society for the Study of Education[44] proposed the following criteria for the selection of content in science for the junior high school.

Content for Junior High School Science should:

(1) Be in harmony with the accepted objectives set for the pupils;
(2) Lead to the inculcation of appropriate scientific attitudes and the understanding of the methods of science;
(3) Encourage the belief in, and practice of, desirable social ideals involving science;
(4) Be of direct use to pupils in their daily living;
(5) Be appropriate for the ability level of the pupil;
(6) Aid pupils in the interpretation of the local and world environment;
(7) Be in harmony with the needs and interests of pupils.

Selecting content for the specialized sciences of the senior high school. It has been previously noted that of the sciences usually offered on the senior high school levels biology is most commonly offered on the tenth year level with physics, chemistry, and physical science offered in different sequences in the last two years. Of these courses, biology seems definitely to be meeting sufficient of the needs of pupils to have maintained its enrollment. Physical science, because of its newness in the curriculum and the uniqueness of its materials, may be assumed to be meeting the needs of young people who take it although there is at present little evidence to warrant conclusions. Physics and chemistry seem to be gradually losing ground as judged by percentage enrollments in them from year to year.

This condition of physics and chemistry may in part be due to the nature of the materials selected for instruction. With the rapid advances, over the years, in these branches of science the tendency has been to always add materials to the courses without deleting older materials. Perhaps greater attention needs to be directed to a more careful selection of instructional materials in these areas with a view to making them contribute more to the adjustment of the young people who study them.

Many qualified teachers are in agreement that both the course in physics and in chemistry contain much more material than can be taught effectively in a one year term. This would seem to argue for selecting fewer topics for each of these courses. It is reasonable to believe that in an age when physical science is creating so many adjustment problems for young people through technological advances that the study of physics and chemistry in high school would have much to contribute to the training of these same young people.

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[44] *Op. cit.*

One of the factors which has restrained the courses in physics and chemistry from becoming more functional is the continued influence of colleges and accrediting agencies. Textbooks in these sciences are still written to meet the needs of college entrance despite the fact that these influences have become much more liberal over the past decade. It is probably true that one reason general science and biology have seemed to meet the adjustment needs of boys and girls more effectively is that they are a little further removed from the influence of the colleges.

The course in physical science, judging by the instructional materials selected by the authors of some textbooks, and by materials proposed in certain courses of study, seems to be much more functional than either of the other specialized physical sciences. The present situation regarding this newer course is so much in a state of flux that it is difficult to ascertain what the trend for physics and chemistry should be. There is a considerable tendency on the part of some in the field of secondary science to believe that the courses in physics and chemistry should be retained much in their present form but offered only to those pupils who plan to go on in some field of science as a profession. This would then leave the course in physical science to take care of the functional needs of the young people not interested in specializing in science.

As was true on the junior high school levels the studies made of the growth characteristics of young people can help provide a sound basis for the selection of functional content on the senior high school level. The following list has been selected as a typical of these characteristics, but no attempt has been made to make it complete.

Young people on the Senior High School levels:

(1) tend to grow in independence and to resent domination of authority especially of adults,
(2) tend to grow in idealism and in the development of desirable attitudes such as tolerance and open-mindedness,
(3) are in a period of rapid growth and therefore may be awkward and clumsy in physical manipulation,

(4) evidence the varying maturity of the sexes more sharply than at the lower levels,
(5) seek earnestly to understand themselves in relation to others especially those of the opposite sex,
(6) are groping for answers in the field of values such the meaning of success, the nature of life, etc.,
(7) are experiencing a period of intense specialized interests,
(8) are growing in the skills needed for abstract thinking and problem solving,
(9) want to deal with their problems on a mature level but seek guidance from their elders,
(10) are intensely interested in materials for which they can see immediate application,
(11) are exceedingly realistic and desire to have materials treated "in the raw" rather than glamourized.

Several important studies of the essential science principles for secondary school science have been made. Among these the following are mentioned as typical:

Pruitt[45] made a study of essential principles in chemistry, Wise[46] studied the relative importance of the principles of physical science for general education, and Martin[47] made a study of the principles of biological science important for general education.

THE ORGANIZATION OF LEARNING MATERIALS IN SCIENCE

The functions of organization. The type of organization used, once instructional materials have been selected, may be a salient factor in the effectiveness of learning. It may determine, for example, whether learning will result in a mere memorization of facts and principles, or functional understanding of concepts and principles;

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[45] Pruitt, Clarence M., "An Analysis, Evaluation, and Synthesis of Subject matter, Concepts, and Generalizations in Chemistry." Ph.D. Dissertation, Teachers College, Columbia University, New York, 1935 also in Curtis, "Third Digest of Investigations in the Teaching of Science," The Blakiston Co., Philadelphia, 1936, p. 153.

[46] Wise, Harold E., "A Determination of the Relative Importance of Principles of Physical Science for General Education." Ph.D. Thesis, University of Michigan, 1941. Reported in *Science Education* XXV: 371–379 and XXVI: 8–12, Dec. 1941 and Jan. 1942.

[47] Martin, W. Edgar, "A Determination of Principles of Biological Science Important for General Education." Ph.D. Thesis, University of Michigan, 1944. Reported in *Science Education* XXIX: 45–52, 100–105, 152–163 February, March and April 1945.

whether or not the pupil develops desirable attitudes, interests and appreciations; and, whether he grows in the skills of problem solving. It is very important that teachers become familiar with the variety of factors that enter into effective organization so that they may select the best method to achieve the objectives sought.

Organization should provide for the effective learning of facts, concepts and principles. Facts are learned by experiences in a variety of ways. The development of meaning and understanding for concepts and principles comes slowly and only with repeated and varied experience. It is important in planning the organization of materials that opportunity be provided for recurring experience with concepts and principles to provide for the enlargement of understanding. This will be discussed in greater detail in a later chapter.

Organization should provide a natural method of learning that is psychologically sound. Materials should be so ordered, for purposes of instruction, that learning experiences lead naturally toward the objectives sought. In some of the sciences the materials are still organized on the basis of the logic of the science. This often leads to the learning of isolated elements which do not fall into any integrated plan. Association plays a very important role in learning and it is, therefore, imperative that materials be organized so that patterns of integration emerge as learning progresses.

Organization should provide for the development of the skills of problem solving. If we may assume that the problem solving objective is important then the organization of materials must be planned to give continued and recurrent experience with these skills. Problem-solving skills do not develop concommitantly from mere association with science materials. They must be practiced over and over in the daily work of the classroom if the pupil is to develop proficiency in their use.

Organization must provide for the development of desirable attitudes. Again these emerge and develop slowly and the pupil must be confronted with situations involving these attitudes day after day. These situations do not develop incidentally, but must be planned for in the organization of learning materials.

The remainder of this Chapter will be devoted to discussions of the various types of organization that have been used for instructional materials in science. There probably is no one-best method of organization and so familiarity with several methods may enable the teacher to select the one best suited to the objectives that are sought.

Organization in terms of the logic of the science. This method of organizing materials is probably the oldest of all. It began when courses in high-school science were patterned after the college courses. Most of the high-school science courses were organized on this pattern between 1870 and 1910. Some courses in physics and chemistry still retain the pattern. The organization of physics into the five divisions of mechanics, heat, electricity, sound, and light is an example. Some chemistry books devote much of the second half of the course to a logical treatment of elements and compounds in the familiar pattern of occurrence, preparation, properties, and uses. In the early days of general science the course was divided on the basis of the different sciences that composed it. This was also true of the earlier biology courses when one part was devoted to animal biology, another to plant biology, and a third to human biology.

When the mastery of content is the end sought in learning the logical pattern of organization may have some advantages.

Organization around major concepts of science. The *Thirty-first Yearbook* of the National Society for the Study of Education[48] proposed a scheme of organization about the major concepts of science. The proposals of this committee were stated as follows:

> It is proposed that the curriculum in science for a program of general education be organized about large objectives, that understanding and enlargement of these objectives shall constitute the contribution of science teaching to the utimate aim of education, and that the course of study be so organized that each succeeding grade level shall present an increasingly enlarged and increasingly mature development of the objective.

Samples of the types of science concepts proposed as organization cores have been mentioned earlier in this chapter. This plan of organization has the merit of providing an integrated pattern of organization, reducing the number of topics and providing for the enlargement of concepts from level to level in the school program.

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[45] *Op. cit.*, p. 44.

Organization in terms of environmental units. This pattern of organization for science materials has been widely used on all levels of instruction. It was first used in the course in general science, later in elementary science, and to some extent in the specialized sciences of the senior high school. It has the advantages of teaching for adaptation, utilizing a natural setting for learning, providing for individual differences, and permitting more complete mastery of content materials.

The pattern of the environmental unit as a device for effective learning will be discussed in a later Chapter. As used in general science, for organization, such headings as the following may be found: Air; Weather; Fire; Food; Heat in the Home; Light in the Home; Living Things; Transportation; Communication, etc. Each of these would seem to be a major aspect of the environment containing elements to which a pupil might have to adjust.

As used in biology such units as the following have been used as a basis of organization: Plants and the World's Food Supply; Conservation of Living Things; The Control of Disease; How Do Living Things Keep Alive?; How Do Living Things Reproduce?; The Continuance and Improvement of Living Things. Some recent courses of study in chemistry are also organized around such units as: Chemistry of the Individual; Chemistry of the Home; Chemistry of the Community. In physics such units are: Learning To Use Machines; How Molecules Work For Us In Liquids; Sounds of the World About Us; and, Light In The Home. In the newer course in Physical Science such units as the following may be found: How Does Man Adjust Himself To Air, and Water as Essential Materials for Life?; How Does Man Adjust Himself To Heat?

Organization around the maturing interest of pupils. This plan of organization is not used by itself but in conjunction with other methods. It is an attempt to base the courses on a pattern of enlarging and maturing interests of young people. In most instances this plan has been based on the large number of interest studies that have been made of elementary and junior high school pupils.

The pattern has been used widely in the planning of courses of study on both the elementary and junior high school levels. The

Forty-Sixth Yearbook of the National Society for the Study of Education[49] says:

> In searching for a practical pattern upon which to develop such a spiralled grade placement of junior high school science, course-of-study planners and authors of textbooks have arrived at the following general formula:
>
> First year: Science experiences having to do with the immediately personal problems of the learner and with simple understandings.
>
> Second Year: Science experiences dealing with the physical and community environment.
>
> Third Year: Science experiences dealing with wider social significances of science and the use of science for the control of environment.

While this pattern no doubt has some basis of validity in the maturing interests of junior high school pupils, it is not based upon the findings of carefully controlled studies.

Organization in terms of types of adjustments. There has been some work done in an attempt to organize science courses on the secondary level in terms of the types of adjustments that young people are called upon to make. The Committee on the Function of Science In General Education, Commission on the Secondary School Curriculum of the Progressive Education Association[50] proposed the following types of adjustments as organizing cores for materials in science:

(1) Immediate Personal-Social Relationships
(2) Social-Civic Relationships
(3) Economic Relationships
(4) Reflective Thinking

The Science Committee of the Colorado State Course of Study For Secondary Schools[51] proposed the following types of adjustments:

(A) Adjustments to self-personal adjustments
(B) Adjustments to the immediate social group
(C) Adjustments to the community
(D) Adjustments to economic relationships

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[49] *Op. cit.*, p. 158.

[50] *Science In General Education,* Report of the Committee on the Functions of Science In General Education, Commission on Secondary School Curriculum, Progressive Education Association, D. Appleton-Century Co., New York, 1938.

[51] *Op. cit.*

The scheme of organization to provide for the types of adjustments to be made by individuals would probably not, in and of itself, be used as a pattern of organization but in connection with some of the other patterns proposed above.

Organization on the basis of the areas of human experience. There has been a growing tendency on the part of some curriculum workers in recent years to organize science materials around certain of the broad areas of human experience such as Health, Consumership, Safety, Conservation, Recreation, and Vocation. This plan again has not been used exclusively as a pattern but there seems to be a growing interest in seeing that these large areas are integrated into the pattern of secondary school science.

The unit-problem plan of organization for science materials. This plan for organizing science materials is similar to the environmental unit plan but differs in certain essential respects. The environmental unit plan when first used had as one of its ideas the mastery of content. In the unit problem type of organization the mastery of content principles is only one, and probably a subsidiary, outcome sought. Other outcomes, equally important with the development of understanding of concepts and principles, are desirable attitudes and skills in problem solving.

In the unit-problem scheme the unit is organized around some major problem of adjustment such as, "How do communities secure a pure water supply?" or "How are diseases controlled?" These major problems are then sub-divided into smaller learning problems as for example:

Unit Problem: How do communities secure a pure water supply?
  Learning Problem 1. What types of impurities are found in water?
  Learning Problem 2. Where do the impurities found in water come from?
  Learning Problem 3. How are suspended impurities removed from water?
  Learning Problem 4. How are dissolved impurities removed from water?

This plan of organization is very flexible. It is easily adapted to different techniques of instruction and has many of the good points of other plans. It is especially adaptabe to an inductive, or developmental plan of instruction wherein problem-solving skills and attitudes may be developed. At the same time this plan has proved very effective for developing understanding for concepts and principles.

General principles for the organization of content in science. Regardless of the level for which science content is being organized or the specific problems of organization in a given situation, there are a group of guiding principles which may be used as criteria. These have been well summarized in the *Forty-sixth Yearbook* of the National Society for the Study of Education[52] as follows:

(1) Content should be organized into large areas or units, each of which represents some major problem of living, area of human experience, or aspect of environment.
(2) The content of any single area or unit should be broken down into smaller learning problems which have interest, significance, and usefulness to the learner.
(3) The learning experience in any single problem should be organized to promote functional understandings, growth in instrumental skills, growth in the processes of problem-solving, and the development of attitudes, appreciations, and interests.
(4) Abundant opportunities should be provided both for building and applying concepts and principles.
(5) Provision should be made for effective evaluation including self-evaluation.
(6) The sequence of units should be planned to give recurrent contacts with facts, concepts and principles of science and to provide a spiralling and enlarging pattern of growth in concepts and principles.
(7) Problem situations should provide definite training in one or more of the elements of scientific method.
(8) The course in science should be organized to provide frequent opportunity for pupils to participate in planning and to engage in individual and group projects.

QUESTIONS AND EXERCISES

1. Make an investigation of the findings of the interest studies that are mentioned on page 59. Are there any general conclusions that may be drawn?

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[52] *Op. cit.*, p. 159.

2. From a copy of the *Thirty-first Yearbook* of the National Society for the Study of Education secure a complete list of the generalizations proposed as a basis of organization of science content. Analyze these into facts, concepts, and principles.
3. Go over the lists of growth traits for pupils proposed in this chapter. Write a critical evaluation of one of the lists from the point of view of the items it contains and the influence it should have in the selection of content.
4. Assume that you are a teacher of science on one of the three school levels, elementary, junior high, or senior high. Further assume that you have been given the problem of selecting the content for a unit on health (or some other area) for a given grade level. Make an analysis of how you would go about getting evidence on childrens' needs as a basis for selecting the content.
5. Compare the two lists of principles for selecting content for the elementary and high schools. In what ways are they similar? In what ways different?
6. Indicate how you would weigh each of the proposed principles for selecting content for the elementary school if you were confronted with the problem of selecting materials for a course in elementary science. Repeat the exercise for some selected course on the high school level.
7. Indicate ways in which teachers might bring pressure to bear on publishing companies to produce textbooks that would better meet the needs of young people.
8. Using the factors to be considered in the selection of a science textbook given on page 66, make up a science score card. Analyze each of the major headings proposed into more specific items, and then devise a number weighing scheme for each of the sections and for each of the items in a section. Discuss these score cards in class and agree on a class score card.
9. Apply the class score card to a group of science textbooks and compare the ratings given by different students to the same book. What is your opinion on the reliability of a textbook score card for selecting books?
10. Show how the organization of content might be a factor in learning.
11. Select some textbooks from different levels of the school curriculum and analyze them for the type of organization used.
12. Show how you would plan to reorganize the materials for some selected unit of work if the textbook in use was organized on the basis of the logic of the science and you wished to use a unit-problem type of organization.
13. Select some environmental unit in the science area. Show how you would organize the materials of the unit for each of the following levels:

(1) A class in sixth grade of the elementary school
(2) A class in the ninth grade of the junior high school
(3) A class studying physical or biological science on the senior high school level.

14. Show how some course in junior or senior high school science might be organized in terms of the adjustment areas proposed in the book "Science in General Education," listed on page 74.
15. Examine several three-book series for science in the junior high school. To what extent does the formula given on page 74 apply in the sets of books you examine? Write a criticism of the proposed formula.
16. Write a critical evaluation of the general principles proposed on page 74 for the organization of content in science.

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Chapter 5

THE FOUNDATIONS OF METHOD IN SCIENCE INSTRUCTION

It has been said that teaching is both an art and a science but what in teaching is the art and what the science has never been clearly delineated. Nor is it of much concern to the teacher confronted on a day in September by a roomful of somewhat anxious, but perhaps reluctant pupils. A group that is as varying as its numbers with respect to age, physical maturity, emotional and intellectual maturity, skills, appreciations, background, understanding, and perhaps race, this is the clay, with which the teacher must work; the raw material that has the imprints of other moulds, some good and some bad. It is his task to try to remove the faulty imprints of previous moulds and to add, through the deftness of his artistry, something of lasting worth to the growing creation.

The task that confronts a teacher is one of high complexity and one which carries with it the deepest obligations. It is a task unequalled in any other profession for the need of deep understanding and fineness of skill. At the outset, the task, when analyzed into all of its meanings and ramifications, seems almost hopeless and impossible. And yet year after year in thousands of classrooms over this and other lands, it is attacked by teachers and carried through, for good or ill, in proportion to the understanding and the deftness of skill that are the working tools of these teachers.

In this chapter the authors will seek to present, and clarify to some extent, the basic and fundamental determinants of method in the teaching of science. In later chapters the specific methods for teaching science will be examined and appraised.

THE FUNCTION AND NATURE OF INSTRUCTIONAL TECHNIQUES

When one considers the many differences in a room full of pupils and the desire of the teacher to help each individual develop in the directions pointed by the outcomes sought, the problem of teaching reduces itself to the most efficient use of the time available. This forces the teacher to consider those procedures which may be useful in reaching the desired ends and to select those which give promise of being most effective.

Teachers sometimes make the mistake of selecting one method and of clinging to it slavishly through an entire year. Such practice may be detrimental to the growth toward some of the outcomes sought. Experience seems to indicate that one approach or technique may be more fruitful in one situation while some other approach may provide greater growth in another situation. Every learning unit, perhaps every learning experience, should be carefully appraised by the teacher in terms of its potentialities for attaining the outcomes sought. To sum up, one might say there is no one best method of instruction.

Instructional techniques are aids to the growth of the learner. So conceived, the teacher will constantly keep before her the outcomes that have been set up for the course. Lessons will be planned and learning experiences will be set in terms of the needs of the learner and the particular unit of instruction being taught.

By way of illustration let us assume that a problem dealing with how our buildings are kept warm is being considered in a unit on health. The teacher has had difficulty in getting the pupils to see that the windows over the steam radiators should not be opened at the bottom because of impairing the flow of steam through the system. This is identified as a real need from the point of view of the health of the pupils. To get evidence on why the practice of opening the windows over the steam radiators is bad the teacher might explain the situation; again the pupils might be sent to books or an experiment might be done. However, the teacher weighs all of these and decides that a trip to the basement to see the school heating plant and to have an explanation by the heating engineer or fireman in the building will be far more fruitful in reaching the desired outcome.

Instructional techniques must be flexible. In making plans for a series of learning experiences teachers should remember that things can happen to upset the best made plans. The resourceful teacher will conceive of a plan for a lesson as only a guide within broad limits and will be alert to lay hold of any unique situation that may arise spontaneously in the classroom and which may prove more effective than the plan previously made. For example, a teacher had made what seemed to be a very interesting and promising plan for developing the principle of transpiration in plants with a ninth grade general science class. The class was moving along smoothly when a girl raised her hand and said, "Couldn't we collect some evidence about this by doing an experiment?" The teacher replied, "We must hurry along now, tomorrow is the day for experiments."

This teacher was obviously a slave to a lesson plan. What an opportunity this was for putting the prepared plan aside and letting the pupils work out some controlled experiment on transpiration! Or even of assigning them the job of planning such experiments to be brought in for testing on the next day. Teachers should never be afraid to venture away from set plans as this may prove more valuable for real learning experiences.

Some teachers hoard lesson plans from year to year and teach the same materials in the same way time after time. This is one of the surest means of "going to seed" early. This does not mean that notes and evaluations on certain instructional techniques should be discarded. It rather implies that if the teacher wishes to keep interest in her class at top pitch she must have interest and enthusiasm herself. One way of keeping fresh from year to year, even on things you have taught over and over again, is to plan anew each year just as though it were the first time you were teaching the topic.

It is essential that pupils and teacher plan together. Many interpret this to mean that pupils do only what they want to do. Nothing could be farther from the true meaning of cooperative planning. As long as schools are set up as they are now with classes taught by teachers, the teacher must, and should be, the dominant force in the classroom. Even in cooperative planning the teacher must have a plan. She is the one who can take the long look ahead while the pupils are limited to what has been studied, in their outlook. With a plan in mind, the teacher goes into the classroom and develops the plan with the pupils. One earmark of a resourceful teacher is the ability to have her plan accepted by the pupils and modified and developed by them, until it becomes essentially their own.

In making lesson plans there are several factors which the teacher must keep in mind. First among these is the nature of the learner. The teacher will need to have intimate knowledge of the physiological development of the class so that provision may be made for such things as fatigue, attention span, and the like. For very young children frequent periods of unrestricted play with science toys and materials may make for effective learning. Even with junior high school pupils there is need of planning for activities other than just sitting through a class period and working at a desk.

In making plans for science learnings the teacher will need also to be aware of the range of intellectual maturity in the group. The teacher must decide where to pitch the level of instruction so that it will stimulate the most able and yet provide effectively for those who are less able or less mature intellectually. This factor may even call for the provision of reading materials on the topic of different degrees of difficulty.

The above mentioned aspects of the learner are essentially individual differences. There are other important differences of the individuals in the class that must be considered in planning. Every group will show a range of manipulative skills. Some pupils will be able to handle equipment with facility and will be able to build simple pieces of equipment. Others in the class will have to have patient understanding and help as they seek to develop such skills.

A second important factor to be kept in mind while making plans is the interests of the group. Studies have revealed that the science interests of young people vary widely and that in many instances they are quite transitory. The teacher must seek to make use of any interests held by the group and so plan the development of a topic that interest will be sustained. It will bear repeating that the interest and enthusiasm of an alert teacher can become very contagious in the group. Young people have an abiding interest in nature materials, in toys that move, and in experimenting. No doubt there are many others also that the resourceful teacher can lay hold of as she plans.

A third factor in planning is to keep in mind both the immediate and the delayed needs of the young people. Some pupils in the group, as has been pointed out, will have immediate need for improving in certain skills of manipulation or perhaps in the skills of reading, outlining, drawing and the like. These must be provided for. On the other hand the delayed needs, those that may be seen in the long look ahead, will have to have attention. As an example, the teacher may see ahead a unit of instruction on some topic that needs an understanding of principles that are being developed currently. These principles will of course be planned for in the light of the later needs.

Other factors that may need to be considered in making plans are the size of the class, the facilities for experimenting, and the equipment that is available. If the class is very large it may not be possible to plan for individual or even small-group experimenting. Again the equipment available may be meager and thus necessitate a demonstration rather than individual experimenting.

The learning cycle in science instruction. The idea of cycle teaching is not new. It has been practiced for many years, perhaps under different names, but the concept seems to have validity at least on the basis of long experience and common usage. The development of meanings for science principles and concepts assumes that as learning progresses the understandings will enlarge. A pupil may deal with the concept of water in an elementary fashion say, in the second grade, and in the fourth grade he may again meet the same concept as it plays a part in weather. In the sixth grade his concept of water may be further enlarged by a consideration of water as an agent of erosion. In general science he will no doubt consider the ways in which pure water for a community is provided. In a similar manner biology, physics, and chemistry may all add to his enlarging concept of water. Such a sequence of enlargement of concepts calls for a cycle of teaching and learning. The principles and concepts must be dealt with in ever new and enlarging, but definitely recurrent, patterns.

It is generally agreed among educators that if a pupil is going to acquire skill in anything he must have repetitive practice in that skill. Thus if he is to become skilled in the elements of problem solving he must practice them over and over. This calls for the use of some cyclical pattern of learning. The same thing is true in the development of attitudes, interests, and appreciations.

The learning cycle may be applied to a large area of instruction such as a unit in general science or it may be applied to the solution of a series of smaller subdivisions such as a series of problems within a unit. In general the learning cycle follows a natural method of working through a perplexity or solving a problem. Dewey has called this a complete act of thought. The steps in this process may be classified as follows:

(1) Sensing the problem or difficulty
(2) Analysis of the problem
(3) Collecting evidence on the problem
(4) Interpreting the evidence
(5) Conclusion and application.

The learning cycle must be planned in such a manner as to provide for types of outcomes of instruction such as:

(1) Growth in the functional understanding of
    (a) facts, (b) concepts, (c) principles.
(2) Growth in instrumental skills
(3) Growth in the skills of problem solving
(4) Growth in attitudes, interests and appreciations.

The learning cycle has been in use over a long period largely because it follows a pattern of learning which has been identified and recognized as effective by both psychologists and educators. A learning situation must begin with some act of motivation or stimulus, be followed by a period of directed learning, and close with some form of reaction or application on the part of the learner. In working out a simple and effective cycle which will provide for the outcomes sought in a course in science, several variations of the following pattern have been proposed.

STEPS IN THE LEARNING OR TEACHING CYCLE

1. Exploring the unit.
    - (a) Pre test of understanding.
    - (b) Recall of previously learned principles.
    - (c) Setting the problems for study.
        - (1) Teacher presents sketch of unit.
        - (2) Demonstrations to raise problems.
        - (3) Moving picture or field trip to raise problems.
        - (4) Pupils relate experiences to identify themselves with unit.
        - (5) Problems are identified and stated.
        - (6) Proposals (hypotheses) for the solution of the problems are made.
    - (d) Cooperative planning for the solution of problems.
2. Experience getting.
    - (a) Collecting evidence on the problems.
        - (1) Reading.
        - (2) Experimenting.
        - (3) Interviews.
        - (4) Field trips.
        - (5) Drawings.
        - (6) Observing demonstrations.
        - (7) Presenting report.
        - (8) Presenting demonstrations.
        - (9) Moving pictures.
        - (10) Radio programs.
    - (b) Interpreting evidence.
        - (1) Observing similarities in data.
        - (2) Observing differences in data.
        - (3) Seeing cause and effect relationships.
        - (4) Judging the adequacy of data.
        - (5) Identifying assumptions.
    - (c) Formulating hypotheses.
    - (d) Testing hypotheses.
        - (1) Controlled experimentation.
    - (e) Reaching conclusions.
3. Organization of learnings.
    - (a) Preparation of outlines and summaries.
    - (b) Taking tests.
4. Application of learnings.

The learning experience in the cycle of instruction. Research and experience have indicated that learning is often a slow and prolonged process. A pupil does not suddenly come up with a complete understanding of a general principle or concept nor does he arrive at proficiency in the skills of problem solving except through long and repeated experiences. This means that within the broad framework of the learning and teaching cycle, the teacher must give meticulous care to the planning of specific learning experiences that are designed to build meanings for concepts and principles; give practice in skills; develop interests, attitudes, and appreciations. The often repeated phrase that "the learning experience is at the heart of all teaching" is not merely a trite expression. In the remaining part of this chapter some general types of learning experiences will be discussed. In Chapters VI and VII more specific consideration of learning experiences will be made.

Types of learning experiences for developing functional knowledges. No other aspect of learning has been emphasized more than the mastery of content. In many courses in science it has been sought as an end in itself and has been the sole measure of total learning. The acquiring of functional knowledge is important but must be regarded as a means to the end of solving adjustment problems. There can be little doubt but that inability of young people to do the type of thinking demanded in problem solving, stems in part from the lack of a sound body of knowledge of facts, concepts, and principles, by means of which to analyze problems.

There are a large number of learning studies in the area of science education and in other areas of the curriculum which reveal the inadequacies of learning experiences for providing pupils with a sound body of knowledge. Tyler[1] has summarized these defects as follows:

(1) Students memorize by rote without acquiring real understanding of principles.
(2) Students show a very rapid rate of forgetting.
(3) Students do not organize information but remember it only as isolated and unrelated facts.

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[1] Tyler, Ralph W., "Basic Principles of Curriculum and Instruction." (Mimeographed) Distributed by the University of Chicago Book Store, 5820 Kenwood Ave., Chicago, Ill.

(4) The degree of vagueness and inaccuracy in what students recall.
(5) Students show very limited familiarity with sources of accurate and recent information.

Science teachers can eradicate many of these inadequacies by the careful planning of learning experiences. There is evidence to show that when knowledge is obtained in the course of the solution of problems it is not only retained but that it is actually augumented with the passing of time. This would seem to indicate that learning experiences should be planned in such a way that the pupils' concept structure would be built out of facts and principles learned in connection with the solving of real problems.

Acquiring facts and principles in this way can be a real economy. Many teachers find that in teaching for the outcomes of problem solving it is necessary to sacrifice some content ordinarily covered in the course of the year. On the other hand if the content learned in the solving of problems is retained longer, then the loss mentioned is less real.

One of the ways in which science teachers can make the acquisition of knowledge more effective is to teach pupils how to select more carefully those items that are of most importance. The vocabulary studies that have been made on the various levels of instruction in science reveal the prodigous task that faces a pupil if he does nothing but master the technical terms in any course. Teachers will have to assume the major responsibility for a careful selection of these terms until their numbers are greatly reduced and consist only of those that will be used with sufficient frequency to insure their mastery. In this connection the meanings of the technical terms that are selected should be learned with exactness and precision. One reason that pupils come out of science courses with "fuzzy" and "hazy" concepts is that the meanings of the facts from which the concepts are built are not clear cut.

In making plans for learning experiences within the cycle of instruction teachers must see to it that those items of content that are judged as important must be acquired with sharpness and vividness, and further, that they are brought to the forefront of attention time after time in new contexts and relationships. A pupil may learn that substances condense when changed from a gas to a liquid. Perhaps in the same unit the idea that heat is given out by condensing liquids may be emphasized. In a later context the pupil may learn that the heating of homes and buildings by steam makes use of this principle.

One way of helping pupils to retain important information is to relate it to as many different things already learned as possible. This can be promoted by carefully planning the learning experiences in the phase of the learning cycle related to organization. Pupils do not possess the skills for organizing knowledge. They must be taught and practiced over and over again. Pupils should learn early in their experience with science courses that knowledge can be organized in many ways. The more ways in which the pupil learns to organize his knowledge, the more likely he is to remember it. In the next chapter some schemes for the organization of knowledge in the learning cycle will be presented.

In some ways science textbooks are hindrances to learning, rather than helps, because pupils and teachers alike tend to rely too much on the information that is in the textbook. If pupils are ever to acquire a desire for all the facts on a given problem, teachers must plan the learning experiences in a manner that forces the collection of a wide body of fact on a given problem. This will necessitate that teachers and pupils become familiar with reliable sources of information. Again these skills are not acquired unless they are practiced. In some schools where library facilities are limited the teacher may have to seek out other reliable sources. However even this limitation need not be a handicap with so much free material now available. In the use of free materials published as advertising, teachers will be sure to help pupils judge what is reliable and what is advertising propaganda.

Types of learning experiences in science helpful in developing attitudes. Several lists of attitudes that seem to be important as outcomes of science instruction have been made by science educators. There is considerable agreement among these lists. The following list[2] of attitudes is proposed as suggestive but any other list would serve equally as well. The science program should foster and develop the attitudes which will modify the individuals behavior so that he:

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[2] This analysis is based on outlines originally prepared by committees of the faculties of the Colorado College of Education, Greeley, Col. and the John Burroughs School, Clayton, Mo. and previously reported in the *Forty-Sixth Yearbook* of the National Society for the Study of Education.

1. Looks for the natural causes for things that happen:
    (a) Does not believe in superstitions, such as charms of good or bad luck.
    (b) Believes that there is no connection necessarily between two events just because they happen at the same time or one after the other.
2. Is open-minded toward work and opinion of others and information related to his problem:
    (a) Believes that truth never changes, but his ideas of what is true may change as he gains better understanding of that truth.
    (b) Revises his opinions and conclusions in the light of additional reliable evidence.
    (c) Listens to, observes, or reads evidence supporting ideas contrary to his personal opinions.
    (d) Accepts no conclusion as final or ultimate.
3. Bases opinions and conclusions on adequate evidence:
    (a) Is slow to accept as facts anything not supported by convincing proof.
    (b) Bases his conclusions upon evidence obtained from a variety of dependable sources.
    (c) Searches for the most satisfactory explanation of observed phenomena that the evidence permits.
    (d) Sticks to the facts and refrains from exaggeration.
    (e) Does not permit his personal pride, bias, prejudice, or ambition to pervert the truth.
    (f) Does not make snap judgments or jump to conclusions.
4. Evaluates techniques and procedures used and information obtained:
    (a) Uses a planned procedure in solving his problems.
    (b) Seeks to use the various techniques and procedures which have proved valuable in obtaining evidence.
    (c) Seeks to adapt the various techniques and procedures to the problem at hand.
    (d) Personally considers the evidence and decides whether it relates to the problem.
    (e) Judges whether the evidence is sound, sensible, and complete enough to allow a conclusion to be drawn.
    (f) Selects the most recent, authoritative, and accurate evidence related to the problem.
5. Is curious concerning the things he observes:

(a) Wants to know the "whys," "whats," and "hows" of observed phenomena.
(b) Is not satisfied with vague explanations of his questions.

Tyler[3] has summarized the findings of the learning studies which reveal the ways in which attitudes are developed as follows:

(1) Through assimilation from the environment. The things that are assumed by the people round about us, the points of view that are held by our friends and acquaintances.
(2) Through the emotional effects of certain kinds of experiences. In general, if one has had satisfying experiences in a particular connection, he develops an attitude favorable to some content or aspect of that experience.
(3) Through traumatic experiences, that is experiences that have a deep emotional effect.
(4) Through direct intellectual processes. In some instances when we see the implications of particular behavior, when we analyze the nature of a particular object or process, we are led to develop an attitude favorable or unfavorable to it from the knowledge which we gain from this intellectual analysis.

Tyler[4] further proposes the following suggestions for planning learning experiences to build desirable attitudes:

(1) Increase the degree of consistency of the environment.
(2) Increase the opportunities for making satisfying adjustments to attitude situations.
(3) Provide opportunity for the analysis of problem situations so that a pupil may understand and then reset intellectually in the desirable attitude.

In the chapters which follow suggestions of classroom techniques which may be helpful in developing attitudes will be discussed.

Types of learning experiences in science which may be helpful in developing appreciations. The development of appreciations has become an accepted outcome for science instruction. Perhaps the reasons that it has not received more attention from science teachers is the feeling that it was more the province of such curriculum areas as music, art, and literature and the fact that little has as yet been done on the analysis of the objective. Nixon[5] has defined the term "appreciation" as follows: "Appreciation, which involves both intellectual and emotional elements, is a sensitive awareness to and preception of, the importance or utility of information in its relation to other fields and in the development of attitudes and tastes."

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[3] Tyler, *loc. cit.*
[4] Tyler, *loc. cit.*

In planning learning experiences for the development of appreciations the science teacher should be alert to provide every opportunity for pupils to react favorably to such situations as:

(1) The contributions of science to the progress of civilization.
(2) The methods of problem solving as they have been used by scientists in making discoveries.
(3) The potentialities of science for creating well-being or destruction for the peoples of the earth.
(4) The contributions of science to promoting good health and eliminating disease.
(5) The manifold applications of science through inventions.
(6) The causal role of science in creating social and economic problems and in aiding in their intelligent solution.
(7) The importance of conserving natural resources of many types.
(8) The importance of science for the consumer.
(9) The potentialities of science for raising standards of living.

In the chapters which follow certain classroom techniques for developing appreciations will be discussed.

Types of learning experiences in science which may be helpful in developing interests. As has already been pointed out the studies that have been made of children's interests in science are quite inconclusive other than to indicate that these interests are quite transitory in young pupils. The science teacher will need to consider the matter of interests both from the standpoint of an end and as a means to ends. That is learning experiences will need to be so shaped that they lay hold of the immediate interests of pupils as well as providing for deep and abiding interests in the subject that may function on into adult life, even to the point of use in a vocation or avocation.

The following list is only suggestive of the many avenues of interest that the science teacher will keep in mind in planning learning experiences:

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[5] Nixon, Alfred E., "The Meaning of Appreciation." *Science Education,* XXIX (February, 1945) pp. 35–40.

(1) Interest in some phase of science for a career such as engineering, chemistry, medicine, mining, agriculture, etc.
(2) Interest in amateur photography
(3) Interest in astronomy
(4) Interest in microscopy
(5) Interest in birds as a hobby
(6) Interest in collecting rocks and minerals
(7) Interest in chemistry as a hobby
(8) Interest in botany as a hobby
(9) Interest in gardening
(10) Interest in making scientific equipment

An important factor in the development of interests is to so plan the learning experiences that pupils will derive pleasure and satisfaction from them. In the elementary and junior high-school science abundant opportunity should be provided for pupils to explore many areas in which interests may be developed and to have thrilling experiences in these areas.

Types of learning experiences in science which may be helpful in developing the skills of problem solving. In planning learning experiences for developing the skills of problem solving the teacher should keep constantly in mind that pupils learn to think by reacting time after time to situations that demand thinking. A cursory examination of textbooks in science that are organized on the problem plan will reveal, for the most part, that the problems proposed are not really problems at all in the strictest sense of the word. In most cases they are so set up as to demand, at the most, only a little search in a textbook to find the answer. If pupils are faced with problems that are real to them and for which no textbook answer is immediately available, they are much more likely to engage in processes that will develop skill in thinking.

Science provides abundant opportunities for planning learning experiences that will develop both the skills of inductive and deductive thinking. In the former the learner will be faced with situations where he must draw inferences and generalizations from sets of specific data. In deductive thinking he will react in learning experiences that demand the application of generalizations in some new and unique situations.

Many analyses of the problem solving objective have been made. The following outline[6] is proposed to suggest some of the types of skills that must be provided for as teachers make specific plans for learning experiences to give practice in the elements of this objective. In many instances the outline will suggest types of learning experiences that may be used.

1. Sensing significant problems
    - (a) Sensing situations involving personal and social problems where science knowledge and skills can be profitably used
    - (b) Recognizing specific problems in these situations
2. Defining problem situations
    - (a) Isolating the single major idea of the problem
    - (b) Stating the problem (question) in definite and concise language
    - (c) Selecting the key words of a problem
    - (d) Defining key words as a means of getting a better understanding of the problem.
3. Studying the situation for all facts and clues bearing upon the problem
    - (a) Learning to recognize valid evidence
    - (b) Recalling past experiences which bear upon a problem
    - (c) Isolating elements common in experience and problem
    - (d) Using experimental procedures suitable to the solution of a problem
        - (1) Devising experiments appropriate to the solution of a problem
            - (a) Selecting the main factor in the experiment
            - (b) Allowing only one variable
            - (c) Setting up controls for the experimental factor
        - (2) Carrying out the details of the experiment
            - (a) Identifying effects and determining causes
            - (b) Testing the effects of the experimental factor under varying conditions
            - (c) Performing the experiment a sufficient number of times to insure reliable evidence

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[6] This analysis is based on outlines originally prepared by committees of the faculties of the Colorado College of Education, Greeley, Col., and the John Burroughs School, Clayton, Mo., and previously reported in the *Forty-Sixth Yearbook* of the National Society for the Study of Education.

        (d) Determining and recording qualitative and quantitative data
        (e) Developing a logical organization of recorded data
        (f) Generalizing on the basis of data
    (3) Manipulating the laboratory equipment needed in solving a problem with understanding of its function
        (a) Selecting the kinds of equipment or materials that will be helpful in the solution of the problem
        (b) Appraising scales and divisions of scales on measuring instruments
        (c) Avoiding hazards and consequent personal accidents
  (e) Locating source materials
  (f) Using source materials
  (g) Solving mathematical problems necessary in obtaining pertinent data
  (h) Making observations suitable for solving a problem
  (i) Using talks and interviews as sources of information
4. Making the best tentative explanation or hypothesis
  (a) Selecting important factors related to the problem
  (b) Identifying the different relationships which may exist between the factors
5. Selecting the most likely hypothesis
  (a) Analyzing, selecting, and interpreting relevant data
  (b) Judging pertinency or significance of data for the immediate problem
    (1) Checking data against authority
    (2) Recognizing and developing logical sequence of data
  (c) Recognizing weaknesses in data
  (d) Using resourcefulness in proposing new hypotheses
6. Testing the hypothesis by experimental or other means
  (a) Checking the hypothesis with recognized authorities
  (b) Devising experimental procedures suitable for testing the hypothesis
  (c) Organizing data
  (d) Rechecking data for errors in interpretation
  (e) Applying the hypothesis to the problem to determine its adequacy
7. Accepting tentatively or rejecting the hypothesis and testing other hypotheses
8. Drawing conclusions
  (a) Using the hypothesis as a basis for generalizing in terms of similar problem situations

In setting learning experiences for the development of the skills of problem solving the teacher should appraise plans for each day's work in the light of the potentialities for giving practice in one or more of the skills of thinking. It is important that at times pupils experience thinking situations where the complete sequence of abilities from definition of the problem to reaching conclusions is followed. However this need not be a routine practice for the skills are specific and each may be developed apart from the others. That is the plans for one day may include materials that lend themselves to the definition of a problem; on another day the materials may be of such a nature as to provide opportunity for the identification of assumptions, the proposing of hypotheses, or the interpretation of data. The important thing is that in making plans for learning experiences the teacher become habituated to the practice of sensing the most promising opportunities offered by the materials for developing the skills of thinking.

In the chapters which follow several classroom techniques will be proposed for developing the skills of problem solving.

QUESTIONS AND EXERCISES

1. Select a unit from some area of high school science and work out a pre-test that might be used in exploring the unit.
2. Work out plans for setting the problems in the unit selected for Exercise 1. Select demonstrations and write out directions for their presentation.
3. Work out a set of plans for cooperatively planning, with a class, an attack on such a problem as, "Are the health provisions of his community adequate?"
4. Show how a teacher might organize activities, in the Experience Getting or Assimilation period of the learning cycle, on some selected unit, in such a way as to consume as little time as possible and yet to collect a wide body of evidence. (Suggestion: the class might be organized into committees or use some other plan.)
5. Work out a plan of procedure showing how hypotheses proposed by pupils on the solution of a group of learning problems might be used in developing the remainder of the unit.
6. Assume that a class which you are teaching in general science has just reached the point in the learning cycle where they are ready for the

organization activities. You suddenly discover that they have never been taught to make outlines. Show how you would teach this to them.

7. Indicate what remedial procedures might be taken to correct each of the defects of learning listed on page 86.
8. Make an analysis of some of the vocabulary studies that have been made in the area of science teaching and present your findings to the class.
9. Compare the list of attitudes given on page 89 of this chapter with lists prepared by others. Are the lists similar? Are the differences important?
10. Using Tyler's list of ways in which attitudes may be developed, work out a plan for using at least two of them for developing some selected attitudes.
11. Select some appreciation that has a science basis and show how you might develop a plan for presenting it to a high school science class.
12. Compare the outline of problem solving skills proposed here with other lists. Are there differences? How important do you regard the differences?
13. Discuss the importance of learning content as an end in itself, versus content learned as a means to other ends of instruction.
14. Explain why the older point of view that skill in problem solving will develop concomitantly in the study of science taught by any method is probably untenable.
15. Suppose that as a teacher of science in a certain school system you were required to cover a given course of study. How could you find the time needed to give carefully planned drill work in the skills of problem solving?
16. Outline a presentation that you might give to the principal in a school where you were teaching to try to convince him that the development of attitudes, skill in problem solving, appreciations etc. was more important than covering a certain number of prescribed units of instruction. What evidence would you use to back up your presentation?

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Chapter 6

TECHNIQUES OF INSTRUCTION IN SCIENCE FOR THE ELEMENTARY SCHOOL

In the preceding chapter the general aspects of methodology in science teaching were described. In Chapter 2 the major goals of science teaching were delineated. In Chapter 3 the psychology of science teaching was discussed. It may be well for the reader to review these chapters because the principles explained in them are assumed as basic to the content of this chapter and the one to follow.

One of the most important developments in elementary education during the last two decades has been the introduction of science into the curriculum of the elementary school. Not all elementary schools have a well developed science program, but teaching science in the elementary school is being more and more widely accepted as a responsibility by those who are planning the education of children.

Importance of Planning Materials for Learning

Careful planning is necessary if one wishes to be a successful teacher of science. The science teacher who does not plan may be unaware of any particular goals to be sought. Lack of planning also may mean that the teacher does not realize the full significance of the learning material. The relationship between the pupil and the materials of learning constitute a psychological situation. Materials and activities are selected to foster learning. The teacher may greatly influence the type of learning by the principles that he emphasizes in selecting and organizing the materials and activities for the daily science lessons.

Assuming that the elementary school teacher understands his pupils and knows their varying mental capacities and interests, there are three questions that the teacher should ask himself before planning science lessons:

(1) Do I know what science can do for children?
(2) Do I possess the background of knowledge of science to properly guide the children?
(3) Do I know how to plan lessons in science so as to achieve the particular goals of science instruction?

Question number one, "Do I know what science can do for children?" when stated more formally means "What are the major goals of science teaching?" Statements of the goals of science teaching for elementary school science and secondary school science are given in Chapter 2. A careful examination of these statements reveals that there is no great difference in aims between them. Whether it be in the elementary school or the high school the objectives for teaching science are: to teach them facts, concepts and principles of science which they can use in interpreting problems in their environment. To open new avenues of interests and satisfactions. To develop certain scientific ways of thinking and solving problems. To help children grow in their appreciation of things around them and in the work of scientists. If there is any difference between the goals of science teaching at the elementary and secondary school levels it is largely one of degree of achievement rather than one of kind.

Question number two raises a serious problem. Are elementary school teachers prepared to teach science? Some of them are; too large a number are not. All of them agree that children today are interested in science and that the children are continually asking questions which require a knowledge of science to answer. What can the elementary school teacher with inadequate training in science do to strengthen herself as a science teacher? Blough and Blackwood,[1] specialists in elementary science, offer the following helpful suggestions which have been found useful by many elementary school teachers:

(1) Approach the teaching of science with confidence not with the awe usually reserved for the first sight of a two-trunked elephant. It's not as unusual as you think. It's not so much different from

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[1] Blough, G. O., and Blackwood, P. E., *Teaching Elementary Science*, Superintendent of Documents, Washington, D. C., 1948.

teaching social studies, language arts, or arithmetic, in which most teachers feel at ease. It's not harder to teach; in fact, in some ways it is easier because it deals with concrete things and reaches the real interests of many children.

(2) Don't expect to know the answers to all of the science questions children ask you. If you plan to wait until you do, you'll never begin teaching science. Teachers tell children too much anyway. If you know children, and know how to help them learn, half of your teaching battle is won. Don't be afraid to *learn with* children. Let them set up plans for finding the answers to their problems and then you act as a guide and learn with them. Of course you need to know *some* subject matter, but you don't need to be a science specialist. The next few advice items will help you build up some science background.

(3) After a unit or area of science study has been decided on, read some of the basic science textbooks that are on the learning level of the pupils you teach. Read these lower-grade books and then get some good general science or biology textbooks (the kind used in junior high school or tenth grade) and read them.

(4) Do some of the experiments and other activities that are suggested in these books so you'll have the *feel* of the material. These simple science experiments are not half as complex as you may think they are.

(5) Do some of the "things to do" that the books suggest—trips to take, observations to make, experiments to do, collections to make. Seeing is both believing and inspiring and it is much easier to get your pupils interested in and excited about the town's filtration plant if you have yourself seen how wonderful it is.

(6) Talk with a junior high-school science teacher near your school and enlist his help. Secondary teachers often can give you teaching ideas, suggest experiments, and help provide materials and books. Science is their special field and they are usually full of helpful ideas.

Remember that it's the unfamiliar that's likely to make you timid, so give yourself as much first-hand experience as you can with the science material. Following the four preceding suggestions is almost sure to make you confident enough to tackle a new science unit.

(7) Don't feel too handicapped because you lack materials. Children can bring from home almost everything you actually need. What they can't produce, you can get at the dime or hardware store, borrow from the high-school science department, find in the school-yard, get from the school janitor, or let the children make. Expensive complicated apparatus is worse than useless in the ele-

mentary science class. It is likely to be confusing and to draw attention to itself rather than to the problem at hand.

(8) Let pupils experiment. It's one way children learn and they like it. Use some of the more apt pupils in your class to help gather materials and set up the experiments.

(9) Start your science by teaching a unit with which you feel most at home. This may be contrary to the belief of some persons that pupils should initiate all problems for study. Probably the importance of that is open to question anyway. If some of your college science training, a personal hobby, or an intense interest of yours has given you background in some special field, using that knowledge or interest to determine your choice of unit may be your springboard into science teaching. Later it will be easier for you to follow childrens leads. They can always enter into the planning even if the original idea came from you as a teacher.

(10) Make all use possible of the teachers' manuals that accompany your textbook in science. Teachers' manuals are usually packed with teaching ideas that have been tested and found good. They are often helpful even if you are not following the text they have been prepared to accompany.

(11) Keep track of your science material, your notes on reading, your plans, etc., so you can use them at a future time and so that other teachers may borrow them. The second time over a unit is easier, especially if you have access to the material you used before.

(12) Talk to other grade teachers about what things they have found successful, and be ready to share your experience with them. Such an exchange is often a great help.

Question number three refers to the ability of the elementary school teacher to plan lessons in science for children. The purpose of organizing learning material is to provide an orderly background of experience which will in turn make for a better understanding of new situations and increase efficiency in learning.

Guiding Principles for Planning

First and foremost, careful planning of science lessons for children requires that teachers have a guiding philosophy. There are two major points of reference in the organization of learning materials: the experiences of the pupils, and the systematized body of knowledge called science. Depending upon one's point of view there are three possible approaches to planning science activities:

(1) *The psychological approach.* There are educators who believe that science instruction should be based entirely on the demands of the

children. Organization from this standpoint is sometimes characterized by the term "life like." Adherents of this philosophy of organization call attention to the high degree of motivation which it provides. However, exclusive use of this approach to planning restricts the scope of science to random activities. Children's learning may be fragmentary and lack a sustaining framework.

(2) *The logical approach.* This approach to the organization of learning materials is to use the systematic arrangement of knowledge as it is found in the major science fields of biology, chemistry, physics, geology and astronomy. This approach to the study of science may be alright for the mature specialist but for the immature learner it is an unsatisfactory basis for presenting learning materials.

(3) *Flexible planning.* Flexible planning means a plan of organization that includes the desirable characteristics of both the psychological and the logical approach. Such a plan will provide a meaningful succession of topics throughout a course of instruction and will make continual reference to the pupil's background and experiences. Such a plan will also make full allowance for special interests and current events.

Craig[2] speaking of flexible planning says,

> The teacher knows, too, the areas of the environment of which she desires the children to gain increased understanding during the year. Therefore there must be planning as to the areas to be encountered as well as planning with reference to the larger values, or objectives, toward which progress is to be made; but that planning must be flexible, depending entirely upon the understanding of the children and their ability to think in the particular areas. The teacher must plan her instruction with a view to adapting the learning to the learner. Furthermore, she must plan it so that the learner may help to define problems and suggest how the problems are to be solved. The teacher must not expect all groups in a given grade or all children in a given class to reach the same level of developement in the same length of time.

The goal of science instruction is to provide the child with opportunities to adjust himself intellectually to the entire environment. A well-rounded science curriculum is necessary to achieve this ideal. This further means that teachers of science should have a mental picture and a good understanding of the environment. A chart like the one devised by Craig[3] is helpful in giving a balanced view of man's environment.

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[2] Craig, G. S., *Science for the Elementary School Teacher,* Ginn and Co., Boston, 1947.

[3] *Op. cit.,* page 44.

Beyond the Earth	The Earth	Conditions Necessary to Life	Living Things	Physical and Chemical Forces	Man's Attempt to Control His Environment
The earth in relation to the universe Movements of the earth Effect of sun on earth Cause of day and night Cause of seasonal change Relation of earth and moon Cause of tides, eclipses, phases Earth a part of solar system Our own universe Other universes Stars, comets, meteors Gravitation	Weathering of rocks Erosion How rocks are made How soil is made How mountains are made Earthquakes, volcanoes, geysers, caves Structures of the earth Story of the earth Prehistoric life How the earth came to be as it is Forces operating on the earth Changes in appearance, climates, elevation, plants, and animals Changes in the local vicinity Gravity and weight Variety of earth materials Conservation of natural resources	What life needs How plants and animals make use of gravity, warmth, light, water, food, and air What happens when these conditions are changed How some kinds of life are fitted to deserts, swamps, polar regions, etc. Weather changes Past climatic changes Struggle for existence Balance of nature Relation to health and safety	Effect of seasonal change Animal homes Variety of living things Prehistoric animals How animals protect themselves Seed dispersal Social life of animals Animals of today How animals are exterminated Struggle for existence How living things get their food How living things grow up (life cycles) Metamorphosis Balance of nature Economic value Man's influence upon nature Conservation Relation to health	Heat: Changing solids to gases and gases to solids Light Sound Gravity Magnetism Machines do man's work Cause of winds Atmosphere Power and energy Sun a source of energy Chemical changes: Rusting, breathing, etc. Where we get our energy Relation to health and safety	Man's inventions and discoveries Man's use of power Man's use of minerals How man measures things How man studies places he cannot reach, such as interstellar space and core of earth Man's control over living things His errors and successes Attempts to control pests Conservation Importance of scientific attitude and method to society Relation to health and safety Control over environment for sake of man's welfare, comfort, and happiness

Survey of the Environment

The Child

From Craig. G. S., *Science for the Elementary School Teacher.*
Copyright 1947 by Ginn and Co., Boston.

Guiding Principles for Teaching Elementary Science

In the *Forty-Sixth Yearbook* (Part I) of the National Society for the Study of Education[4] a set of guiding principles is proposed by experts in science education for the vitalization of instruction in elementary science. They are as follows:

(1) Instruction should begin with children where they are.
(2) Identification and observation should be viewed as means to interpretation.
(3) Problems and topics should not be pursued beyond the level of the children's span of interest or their level of ability.
(4) Children should be given opportunity to participate in planning.
(5) Children need rich experience with experimentation.
(6) Children need rich experiences with science books.
(7) Provision should be made for the development of special interests.

Many science educators believe that the use of scientific method in teaching science should rank first in the methodology of science teaching. Since scientific method and scientific attitudes have been analyzed in the preceding chapter an exposition of them will not be repeated here. The problem now is, how are science units and lessons initiated and guided with the application of scientific method? How does one begin?

Since scientific method means solving a problem scientifically the teacher must be alert to detect problems that are real and vital to the pupils. Children frequently ask questions that serve as a natural approach to scientific method. Sometimes problems arise when they are least expected. Here is a typical case.

The fifth graders in Miss Jones room were planning an out-of-doors activity for the morning of the next day. One pupil wondered what they would do if it rained! The teacher informed them that the weather man said it would be "clear and sunny" tomorrow. Tomorrow morning came and it was raining. One pupil said, "I just knew it would rain, it always does when the weather man says it is going to be a sunny day." Another pupil said, "Yes, my mother says she always carries an umbrella when the weather man says it will be a clear day." The teacher sensed an opportunity for a good science activity. She asked her class whether they would like to find out how reliable weather predictions were? A problem was raised? They decided to keep a record of the weather man's predictions for each day of a month and also the weather for each day. At the end of the month they found that the weather man's predictions for that month were ninety per cent accurate. The teacher could have told the pupils that weather predictions ranged from about eighty to ninety per cent in accuracy. But by attacking the problem scientifically they learned a great deal more. They learned to keep an open mind, to collect data before arriving at a conclusion and not to generalize on one case.

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[4] Science Education in American Schools, National Society for the Study of Education, *Forty-Sixth Yearbook,* Part I, Chapter 7, University of Chicago Press, 1947.

Blough and Blackwood[5] in their bulletin "Teaching Elementary Science" describe the use of scientific method with problems relating to evaporation and condensation.

Since, for purposes of illustration, a unit for consideration has already been selected, the teacher needs to think of ideas for launching it—for making it interesting, real, concrete, vital, and enjoyable. Where can we begin? Well, the water level in the schoolroom aquarium keeps getting lower and every week or so the water needs to be replenished. Pupils have been curious about this. Water colors in the paint boxes dry up where they are being used and more water must be added. Why? Wet play clothes are hung near heat to help them dry. It rains, the sun comes out, the grass gets dry, and pupils can then go out to play. These are everyday happenings involving evaporation and condensation.

Suppose we use the aquarium as a starting point. Pupils notice that the water keeps disappearing. The question arises: "Where do you suppose the water goes?" Pupils offer their ideas: The aquarium leaks or 'The water goes into the air,' or The fish drink it. "Have you seen other places where water disappears like this?" the teacher asks. Pupils suggest places. "Where do you think this water is going?" she asks. Pupils suggest places. "Sometimes water disappears quickly; sometimes slowly. Why do you suppose this happens?" Pupils give their ideas. Through such a preliminary discussion as this pupils raise problems and interest is aroused. A readiness for the study is coming about. The questions that arise are listed for answering. Some of them may be: What happens to the water when it disappears? Why can't we see it then? Why does it disappear? Could we keep it from disappearing? Can we get it back again? How can we make it disappear faster?

"Now, how do you suppose we can find the answers?" the teacher asks. Suggestions from the pupils are important here. We want them to learn ways to answer their own questions and then to proceed to use these ways so that they will arrive at reliable conclusions. The pupils suggest: Reading, experimenting, asking questions, watching things, and other ways.

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[5] *Op. cit.*

"How shall we begin?" The questions may be arranged in some order that seems logical for answering. A library committee working with the teacher may research for books that will assist in finding the answers. These sources will suggest various experiments and activities. Suggestions have been made for use of reading material, for experimenting, and observing.

In performing experiments, as in all other activities it is essential to keep them geared to the purposes for teaching the unit. For example, we want to help pupils grow in the use of scientific attitude. We say: don't let pupils jump to conclusions, and be sure to use a control in performing experiments whenever possible. In this unit, one of the problems may be: Why do clothes on the line dry faster on a windy day? To solve this problem pupils may perform the experiment of making a wet spot on the blackboard and fanning it with a piece of cardboard. The spot, of course, will soon disappear.

Pupils will decide immediately that the wind made by fanning caused the water to evaporate faster. *But they shouldn't decide that.* As a small, alert boy once said, under such circumstances, I can't remember how big it was to begin with. So the question arises, How can we fix our experiment so we can be sure that wind is helping the water evaporate faster. "Put two spots on the blackboard, fan one and *don't* fan the other," someone suggests. Now you are getting on the track. So two spots are made near each other and fanned. Someone says, Some of the fanning is getting on both spots. What shall we do? someone asks. "Put the spots farther apart," another pupil suggests. This is done, but one of the spots is small, the other large. "There's still something wrong with the experiment," someone says. What is it? The spots must be just alike or we can't decide that the wind is helping. The experiment is tried again. This time with two spots as nearly alike as possible and sufficiently far apart. This time the pupils are willing to decide that this experiment helps them to see that wind helps water to evaporate. But they must be sure to have more experiences before they decide for sure.

"Now have you ever seen other places where wind helps evaporation?" (The teacher has in mind people blowing on ink to make it dry when they can't find a blotter; hair driers; and the like.)

Through this method of keeping careful check on how children draw conclusions they gradually come to be more accurate in their observations and reportings, a situation highly to be desired according to our objectives.

Planning Units in Elementary Science

When learning materials are properly organized a principle of continuity is implied. The principal and the teachers of an elementary school should plan together so that pupils as they pass from grade to grade will gain an ever-widening and deeper understanding of the world in which they live. Carefully planned units for each grade is a means to this end. At the same time the proper organization of a unit in science makes for flexibility rather than rigidity of control in directing learning experiences. The organization of science into units for instruction should be conceived of as a well-marked highway, but at the same time a highway with side trails that reach the backgrounds of experience and knowledge of individual pupils.

The placement of learning materials at proper levels of pupil maturity is an important aspect of unit planning. Subject matter and activities within a unit must be of appropriate difficulty and value for the pupils for whom the unit is being planned. Since the pupils within a certain grade vary greatly in mental ability, experiences and interests the teacher must not expect all the children in her class to attain the same level of understanding in the same length of time.

Let us now examine a unit[6] in science that was planned for use in the second grade. It is not to be implied that this is the only way of planning units in elementary science.

WEATHER

A SECOND GRADE UNIT

Objectives: The child should develop an appreciation and understanding of the scientific attitude. His curiosity should be aroused and satisfied through application of the cause and effect technique. He should begin to look for logical explanations in nature for that phenomena in his immediate environment. Unfounded beliefs, superstitions, and misconceptions should be displaced with truth, and that truth demonstrated within the limits of his possible experience. Confidence should be established in the findings, conclusions, the literature of scientists, authors of scientific material, and the various agencies operating in the field. The interrelationship between the community and the world of science should be stressed. The children should be given a comprehensive test at the conclusion of the unit so as to determine the extent of retention, interest, and whether material and terminology had been presented at their level, and so that the children may have personal proof of achievement in science. The results of this test may also show that sufficient interest exists for some children who are progressing at the average pace, to act as a motivation for learning better the tools of reading, writing, counting, etc. *Procedure:* Daily itemized plans should be formulated. These should contain:

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[6] This unit was planned and taught by Joseph A. DeLuca, a senior student teacher at the New Haven State Teachers College.

(1) Immediate objectives.
(2) Short review of previous day's work by the class so as to determine retention, interest, comprehension, and whether material was presented properly.
(3) Short discussion, by class, of today's activity to discover what preconceived or true ideas children might have.
(4) Check up on "research pupils."
(5) Check up on routine projects e.g. weather reports, art phases (calendar, murals, temperature recordings, etc.).
(6) Put list on blackboard of new words to be learned.
(7) Tell, read, or present as occasion arises new material. Demonstrations must be integrated and not incidental.
(8) Read, or have read stories on subject; also poems and songs.
(9) Ask for questions. Answer some. Leave others for "Research pupils."

Subject matter: The weather—causes and effects, allied areas.

A. Heat "cold."
    (1) Measurement of temperature.
        (a) Need.
        (b) Method.
B. Children's experiences.
    (1) Their explanations—science's explanations.
    (2) Clothing, shelter, etc. and the weather.
C. Wind, moisture, air-pressure, storms.
    (1) Definitions.
    (2) Indicators. (Measurement and theory should be avoided).
    (3) Causes of wind motion and storms broached.
        (a) Air pressure.
        (b) Clouds and winds.
    (4) Weather predictions.
        (a) Establish scientific basis.
        (b) Demonstrate general reliability.
        (c) Value to individuals, farmers, shipping, etc.

(5) Effects of weather phenomena.
  (a) Beneficial.
  (b) Detrimental.

DEMONSTRATIONS AND EXPERIMENTS

(not necessarily in order given)

(1) Have child put finger into pans containing snow, water at room temperature, and heated water. Follow with thermometer readings. Record all readings. Mix snow, in stages, with water, record and have child feel mixture. Draw thermometer on board.

(2) Make a model thermometer with a continuous, movable central strip (for column), half red and half white.

(3) Have as many different types of thermometers for class examination as possible. Illustrate uses, e.g., weather, baking, clinical, bath, industrial, home heating.

(4) Wave fan over radiator; record air temperature; do same with pan of snow. If this is successful, use to demonstrate origin of cold and warm winds.

(5) To demonstrate that air rises when heated, place feather or fluffy material like dried milk-weed seed on table. It remains motionless. Place same over hot radiator, it sails to ceiling. Its eventual downward course shows convection (this phase may or may not be followed up). If the radiator is hot enough, use a pinwheel too.

(6) Take readings on floor, eye level, and near ceiling.

(7) Show water cycle. Put snow or ice into pan. Hold over pan of boiling water. Snow (solid) melts to water (liquid); water boils to steam (vapor) condenses to water. Correlate with rain, etc.

(8) Have "researchers" measure out 20 drops of water into several watch glasses. Set in various places (outside, in sunlit window, shaded window, over radiator, in cool room, etc.). Have periodic checks made to determine rate of evaporation. Have all samples checked each time and results recorded. Analyse result.

(9) Weigh out same amount of ice into two portions. Put rock salt on one. Check rate of melting. Show every day use of salt.

(10) Put toy balloon over neck of Pyrex flask. Heat flask. Balloon will inflate. Submerge flask in snow. Balloon will deflate and depress into flask. Use this to illustrate air pressure. This flask can be left in window. Children will be interested in watching it react to heat changes.

(11) To demonstrate force of air pressure, put burning paper into a milk bottle. Place shelled hard boiled egg, which previously had been demonstrated to be too large to fit into neck of bottle, on this same neck. The egg will bobble about for a moment and then will pop inside, whole. To remove, tilt bottle upward so that egg falls back into lower part of neck; blow hard into neck; egg will come out, whole.

(12) Stage drama game to illustrate approximate eighty per cent reliability of weather predictions by U. S. Bureau. Have one child be local weatherman. Station three others at different intervals as New York, Chicago and St. Louis. Two children will act as Mr. Storm and Miss Wind and as they approach St. Louis, the child there announces, "Mr. Storm and Miss Wind at St. Louis." The child representing the New Haven area says, "Mr. Storm and Miss Wind coming in three days." This is repeated for Chicago and New York except that New Haven says, "in two days" and "tomorrow." Then when Mr. Storm and Miss Wind come up and touch him he says that they are here today. This entire scene is enacted 5 times; however, once, after the New York announcement, Miss Wind leads Mr. Storm away from the New Haven area. Some child then asks the weatherman why they didn't arrive when he had promised that they would. He answers, "Miss Wind changed her mind and took him off in another direction." A chart should be put on the board showing how many times New Haven predicted right and wrong. This game should be staged at the end of the unit so as to be able to show relationship between it and the actual percentage of correct predictions from U. S. Weather Bureau.

(13) Sound and slide films are available. Subjects and titles: Clouds. What Makes Rain. Meteorology and Navigation. (The last should be previewed so as to be able to screen out material beyond their comprehension.)

PROJECTS

Make calendar with symbolic representation for actual weather conditions: rain, cloudy, partly cloudy, snow, storm, etc. Have one child elected Class Recorder. She should draw in, each day, the symbols as per the daily vote of class. Special notation should be made for Weather Bureau forecasts that were wrong.

Have members of one table at a time responsible, for four day intervals, to bring in newspaper weather forecasts. Make folders of same.

Set up record chart for daily temperature readings.

Make variegated pinwheels and weather-vanes.

Arrange for either a trip to Weather Bureau (at airport) or for speaker.

Have children draw scenery with various weather phases.

Songs, poems, stories are to be read, sung, narrated, or recited on weather.

List on blackboard picturesque words that have been found in poems and songs.

Have little stories or poems written in which they may use these words or others they may have in mind.

QUESTIONS AND EXERCISES

1. Make a list of objectives for teaching science in the elementary school.
2. What background of scientific knowledge do you think an elementary school science teacher should possess?
3. If you were teaching science in the elementary school, and a pupil asked a science question you could not answer, what would you do?
4. What are the advantages and disadvantages of the following approaches to planning lessons in elementary science: the psychological approach? the logical approach? flexible planning?
5. Devise a chart which shows the various aspects of our environment.
6. What methods of science instruction are necessary if we wish pupils to develop scientific attitudes?
7. What methods of science instruction are necessary if we wish pupils to develop an understanding of the scientific method?
8. Write out the directions for a controlled experiment for some unit of elementary science.
9. Write out a list of guiding principles for teaching elementary science.
10. Select a unit in elementary science for a particular grade and make a set of detailed plans for teaching the unit.
11. Explain how the "principle of continuity" may be applied in developing a curriculum in science for the elementary school.
12. What criteria would you set up for the proper grade placement of units in science?

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Chapter 7

TECHNIQUES OF INSTRUCTION IN SCIENCE FOR THE JUNIOR AND SENIOR HIGH SCHOOL

In Chapter 5 detailed consideration was given to some of the more general aspects of methodology in science teaching. Chapter 6 has been devoted to a treatment of those techniques of instruction which may be used at the level of the elementary school. In this chapter those techniques which have proved effective on the junior and senior high school levels will be discussed.

While it is generally true that modifications of any technique may be used for purposes of instruction at any level, some devices are better for the elementary level and others for the high school. An approach to a science problem that might be useful in the elementary school could prove hopelessly inadequate when attempted with high school pupils.

In the writing of this chapter the authors have been guided by the thought that the commonplace methods of instruction, such as the lecture-demonstration method, the textbook method and others, have been treated adequately in the literature. Consequently less attention to these methods has been given here to provide more opportunity for discussing methods of dealing with some of the less common outcomes of instruction, such as the development of scientific attitudes, appreciations, interest, and the skills of problem solving.

Techniques of instruction in science will vary with the type of outcome that is sought in any given learning experience. It is also inevitably true that techniques will overlap in the outcomes for which they may provide. As an example, a technique that is useful in developing some aspect of problem solving behavior may at the same time be useful in building meaning for a concept or principle. Or the same technique may yield a return in practicing one or more of the scientific attitudes. In the discussion of techniques which follows the separation into various types is only one of convenience and does not imply that a given instructional plan is suitable only for the situation under discussion.

For purposes of convenient organization it seems desirable to develop this discussion of techniques under the following headings:

(1) Techniques for developing functional knowledges
(2) Techniques for developing scientific attitudes
(3) Techniques for developing appreciations
(4) Techniques for developing interests
(5) Techniques for developing the skills of problem solving

Techniques for Developing Functional Knowledges

Under this outcome of science instruction should be included developing meanings and understandings of particular things as well as developing knowledges about various things. Among the kinds of understandings and meanings to be developed should be included functional facts, concepts, laws, principles, theories, as well as evidence that supports generalizations, conclusions, and ideas.

Chapter 3 has dealt in considerable detail with the psychological principles involved in building up a concept structure. In a similar way Chapter 8 will be devoted to the skills, techniques, and devices for collecting evidence on problems. These chapters thus deal specifically with certain important aspects of the knowledge objective which will be omitted from this chapter or dealt with only in a minor way.

Since the inception of science in the curriculum of the American high school, one of the principal outcomes sought in learning has been the mastery of content. In the early high schools the learning was directed primarily to the mastery of facts. In recent years there has been an increasing tendency to direct learning in science toward its principles and broader generalizations. These trends are encouraging as they lead to a kind of learning which makes content more useful for the student as he faces problems of adjustment in everyday living.

Over the period in which science has been taught in the schools, several methods of instruction have been evolved either by trial and error or by careful experiment. Most of these methods have proved effective in mastering content. It is not to be assumed, from this discussion, that these methods have failed to produce other essential outcomes, but it is true that the chief end sought has been a knowledge of facts and principles. The following discussion will review the advantages and disadvantages of some of the more widely accepted of these techniques.

The lecture method. It has long been recognized that teachers usually teach as they were taught. This tendency introduced the lecture method into the secondary school at an early date. For many years this was practically the only method of teaching science. Later, the lecture plan was modified to include the catechismic plan of recitation. Some of the early science books used in this country were written in a conversational style with the teacher asking a question and a pupil's answer following.

In the use of the lecture method the teacher develops a topic in science more or less from a logical organization. It is now very common, when this method is used, to supplement the lecture with demonstrations and visual aids. It is also a common practice today to have pupils participate in the lecture either by giving part of it or by doing experiments and demonstrations from the demonstration table.

The chief advantage of the lecture method is that it provides an efficient means of covering subject matter and more or less insures that the pupils will receive the material in a concise and logically organized manner. The greatest disadvantage is that the lecturer is usually the only active participant in the process, while the student is a passive recipient of information. In such a situation little responsibility for learning may be assumed by the pupil.

It should not be inferred from this discussion that the lecture method is essentially obsolete. There are many places in modern teaching where the lecture method may be used to advantage, such as in opening up a new unit for study or in summarizing principles at the close of a unit. It may also be used to advantage at many places for giving information bearing on the solution of problems or where for economy of time it is desirable to cover a certain area rapidly.

Whenever the need for using this method of teaching arises the teacher should make careful plans to see that the materials are interesting and well organized and that the ideas presented are clear cut. Our textbooks often fall far short of being inspirational. Teachers may wish to use the lecture method occasionally to relate some of the thrilling historical and biographical incidents in science. The lives of men like Faraday, Priestley, Huxley, Darwin, Mendel and others can supply the materials for many interesting, and perhaps valuable inspirational talks by the teacher.

The demonstration method. The technique of the demonstration will be discussed in Chatper 8 so that aspect of the method will be passed over here. As a device for developing understanding in the pupil for facts, concepts, and principles this method has proven to be very effective. Employed in conjunction with the lecture it may very well become a most efficient method for covering a given section of content in a limited time. It has the advantage of being easily adapted to a logical development of content when the teacher so desires.

The demonstration method has been attacked on the grounds that pupils are often passive when it is used rather than active as they would be in the laboratory. This disadvantage can be overcome to some degree if the teacher assigns demonstrations to be done by pupils. This modification requires that the pupil assemble the materials and try out the demonstration before the class period begins.

This method of instruction need not be one where pupils merely watch and listen. If the teacher uses an inductive approach to the solution of a problem, the demonstration lesson may be so planned that it functions as a controlled experiment. Often much valuable discussion may be directed to the setting up and working of a demonstration experiment.

Many teachers like to use the so-called "silent demonstration" as a means of developing the pupil's skill in accurate observation, recording data, interpreting data, and formulating conclusions. In use the teacher or pupil performs a demonstration and permits no discussion until all the observations have been made. The discussion period that follows is then directed to the recording of observations, the interpretation of data, the formulation of hypotheses, and perhaps further testing.

The demonstration method is also very useful in illustrating applications of principles. After a certain principle has been studied, as many devices as are available for showing the practical applications of the principle are assembled. Here again pupils may be used to advantage in doing some of the demonstrations.

The principal advantage of the demonstration method is perhaps the fact that the teacher is in control of the situation and can thus see to it that the pupil makes all of the essential observations. This is often difficult when the laboratory method is used.

The laboratory method. This technique of teaching in science has in recent years come to connote a learning situation somewhat in contrast and opposition to the demonstration method. Some investigators and writers have set the laboratory technique up as the one in which there is maximum pupil activity and thus where the potentialities for learning are high.

In and of itself, the laboratory method is not one that may be used exclusively. Used in conjunction with some other techniques, it may be a very effective means of collecting evidence in the solution of problems. The laboratory should be a place where a pupil may take a question or a hypothesis and test them under controlled conditions. Too often laboratory work degenerates into mere busy work on the part of pupils. Laboratory directions are followed slavishly and without thought and there is little evidence of controlled experimentation.

If the laboratory method is to produce its maximum effectiveness it must be planned, directed, and controlled by the teacher with just as much care as is used with a demonstration lesson. At times the use of laboratory directions may be a greater hindrance then help. Often fruitful laboratory work follows a discussion where likely hypotheses for the solution of a problem are proposed and considered. Here the pupils plan cooperatively with the teacher in devising ways of testing a given hypothesis and controlling factors, thus making their own directions. With proper planning this method can be used even with the experiments in physics and chemistry.

The *Thirty-First Yearbook* of the National Society for the Study of Education[1] summarizes the things that laboratory instruction should accomplish as follows:

(1) The development of simple laboratory techniques, such as weighing, glass bending, microscopic manipulation, etc.
(2) Proving and establishing for the pupil himself principles which have long since been well established and generally accepted.
(3) Using the laboratory as an instrument for object or 'thing' teaching, according to the historical concepts of Pestalozzi, Comenius and Basedow.
(4) Using the laboratory for the purpose of developing better understanding and interpretations of the principles of science, as a means of better illustration.
(5) To produce training in scientific method.
(6) As a means of possible training in the experimental solution of the pupils' own problems.
(7) The use of the laboratory as a workshop for the study of science problems which arise in the science class or in the life of the pupil.

Under proper guidance and supervision the laboratory method can yield much in training for the development of skills and techniques. The studies of Horton[2] related to basic laboratory skills and techniques, and of Webb and Beauchamp[3] on laboratory resourcefulness show this clearly.

The laboratory method of teaching should produce tested evidence upon which the pupil may base his conclusions. Following are accounts of two discussions that led to controlled experimentation. These were conducted with ninth grade students in a course in general science.

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[1] "A Program For Teaching Science," National Society for the Study of Education, *Thirty-first Yearbook.* 1932 p. 270. Distributed by the University of Chicago Press.

[2] Horton, Ralph E., "Measureable Outcomes of Individual Laboratory Work in High School Chemistry." *Contributions to Education* No. 303. Bureau of Publications, Teachers College Columbia University, New York, 1928.

[3] Webb, H. A., "Testing Laboratory Resourcefulness." *School Science and Mathematics* XXII, 1922. Beauchamp, R. O., and Webb, H. A. "Resourcefulness an Unmeasured Ability." *School Science and Mathematics* XXVII, 1927.

What are the factors affecting the souring of milk? When the milkman delivers a bottle of milk to your home, why is it kept in the refrigerator until used? Why is the refrigerator kept dark? Will pasteurized milk turn sour at the same rate as fresh milk? Will milk with higher butter-fat content sour as quickly as thinner milk? Faster?

A ninth-grade class in general science listed possibilities of temperature, richness of milk, light, pasteurization, age, homogenization. To control all factors but one—the experimental factor—plans were made to use sterilized containers and test, by experiment, the effect of each of the possible influences. Predictions (hypotheses) were made during the discussion of the problem and individual plans submitted. Subsequent class discussions caused some modifications of original plans and a series of controlled experiments started. Parallel and check-up experiments were run by each individual.

Following is a typical summary.

Does pasteurization of milk affect the rate at which milk sours?

Mother drove me out to a farm one evening last month and I had the farmer milk a half-gallon of milk into a pail. The pail had a friction-top cover. We went home and I pasteurized half of it by heating in a double boiler to a temperature of 160 degress Fahrenheit for thirty minutes.

The quart of pasteurized milk was poured into two pint bottles that I had been turning in a pan of boiling water for fifteen minutes. The paper covers which I crimped over and wired down had been heated in an oven for ten minutes at a temperature of 180 degrees Fahrenheit.

The quart of unpasteurized milk was poured into two pint bottles (also sterilized by boiling water). The four pint bottles were labeled as follows: unpasteurized cold, pasteurized cold, unpasteurized warm, pasteurized warm.

The bottles labeled unpasteurized cold and pasteurized cold were set in the refirigerator where a thermometer, left there while the milk was being prepared, showed a temperature of 48 degrees, Fahrenheit. The other two bottles were placed under a hot water radiator. The thermometer reading there, after 10 minutes, was 78 degrees, Fahrenheit. Since the furnace operates by a thermostat and opened doors do not permit much draft upon that part of the room where the bottles were placed, I suppose that there was little change in temperature at any time—the thermostat was not set back during the night.

My prediction was that, because some of the lactic acid bacteria might be killed by the pasteurization, that the bacteria in the unpasteurized milk would cause it to sour first, in both the refrigerator and under the radiator.

Each day at 7:00 a. m., I observed the four pint bottles and noticed the smell, color, and effect of the contents on blue litmus paper. The results are as follows:

		Pasteurized		Not Pasteurized	
Date	Time of Day	Warm	Cold	Warm	Cold
Dec. 8	6:45 p.m.	(milk was secured, prepared and placed)			
Dec. 9	7:00 a.m.	stale odor	no odor	stale odor	no odor
Dec. 10	7:00 a.m.	sour odor	no odor	sour odor	no odor
Dec. 11	7:00 a.m.	very sour	slightly soured	very sour	slight sour odor
Dec. 12	7:00 a.m.	very sour	certain sourness	very sour	definite sourness
Dec. 13	7:00 a.m.	(contents of all bottles seemed identical in every way. I emptied them and washed bottles.)			

On December 9, there was no change of the moistened blue litmus after the milk was shaken by turning upside down 20 times. On December 10 the milk in the warm bottles turned blue litmus red. The cream in a lump in the middle of the bottle and around it was an amber liquid. I could see nothing different in the cold bottles from the day before. On December 11 the blue litmus strips turned red in all four bottles. The warm bottles had a stronger, sour odor than the day before but no change in color. The cold bottles were yellowed a bit. On December 12 the warm bottles were foamy looking. The cold bottles at the top and around the lumps in them looked like the white of raw egg. All blue litmus turned red.

My conclusion is that pasteurization has no effect upon the rate at which milk sours if other factors are the same for both the pasteurized and the unpasteurized samples.

What factors affect the change of cabbage to sauerkraut? When controlled experimentation has been emphasized in the work of the eighth-year science classes, it is no occasion for surprise to walk into the laboratory on any day during the next year and have a half dozen students raise their hands before any demonstrations start or before discussion is begun. Such was my experience last semester after the assignment which included information regarding the work of lactic acid bacteria in converting cabbage into sauerkraut. "Are they the same bacteria that cause milk to sour? How is the cabbage fixed? Can we make some sauerkraut? Would it be all right to eat? Would it be the same kind as that bought in cans at a grocery store? Can we try lettuce instead of cabbage?"

What are the factors that affect the changing of cabbage into sauerkraut? We listed the amount of salt added, the temperature maintained during the time the sauerkraut is forming, the fineness (or coarseness) of shredding the cabbage, the tightness with which the cabbage is packed into containers, the moisture in the cabbage leaves, the possible effect of light or darkness and the length of time the cabbage is cut off the plant before shredding.

Hypotheses were proposed during the discussion of the possible factors affecting the preparation of the cabbage and individual plans were made for starting a series of controlled experiments to test the hypotheses. Voluntary choice of experimental factor was permitted, as all the factors listed were chosen by at least two students as their experimental factor.

Following is a summary written by one student.

Does the coarseness with which cabbage is cut (shredded) have any effect upon the time needed for it to turn to sauerkraut?

My experiment was to find the effect of the coarseness with which the cabbage is chopped in making sauerkraut. The experimental factor was the coarseness with which the cabbage was chopped.

On Sunday, I sterilized two jars and their tops by placing them in boiling water. In one of these I packed finely-cut cabbage very tightly and placed one-half of a tablespoonful of table salt on top of the cabbage. In the other, I packed coarsely-cut cabbage from the same head of cabbage as before and from the same outer leaves of the head; packing each with equal tightness and with the same amount of salt from the same salt box.

Following this I screwed the tops loosely on the jars and wrapped paper around the jars and tied it on to keep out the light. Both jars were placed in a fairly cool, dark place in the basement.

On the following Wednesday, I repeated this experiment in every detail, using two other jars.

On Monday, I examined the two jars that I had prepared the first time. Neither of them had turned to sauerkraut although there was some traces of decay. Neither possessed any odor and on the top of the cabbage in both of the jars was a small amount of damp salt. The finely chopped cabbage had slight traces of decay which were evenly distributed. The coarsely chopped cabbage had almost no traces of decay. Both still resembled cabbage and had very little moisture.

On Thursday, I examined the two jars that were prepared the second time (the same number of days earlier that are described in the above paragraph). Both had a faint musty odor and little moisture.

Most of the particles of finely chopped cabbage were white, although some had begun to decay or were already decayed and were gray or partly black and a few were light green. There was a little bit of damp salt on top of both which had hardened into small lumps. Most of the particles of coarsely chopped cabbage were white; a few, however, had decayed and were completely black or gray with black edges. There appeared to be more moisture in the jar containing coarsely cut cabbage. There were larger and more air spaces in this jar because the cabbage could not be packed down as compactly.

The cabbage and conditions inside the two jars of finely cut cabbage resembled each other fairly closely, as did the cabbage and conditions inside the two jars of coarsely cut cabbage.

A week later revealed quite a change in both pairs of jars. The finely cut cabbage was quite sour, less decayed on top and had the odor of sauerkraut.

At the end of three weeks› the finely cut cabbage was, except for a layer on top, completely converted into sauerkraut. More than half of the cabbage in the jars containing coarsely cut cabbage, originally, was dry and decayed.

At the end of the fourth week, I purchased at a store a can of sauerkraut. Its contents were more like the contents of the finely chopped cabbage that had been prepared. The store cabbage had more moisture but no noticeable difference in taste could be found.

My conclusions are that the finer cabbage is chopped the more evenly the sourness spreads and the more moisture is formed the more rapidly the sauerkraut is produced; that finely cut cabbage has its moisture drawn out by the salt more quickly.

The textbook method. From the earliest period of science teaching in America the textbook has been an essential aid to learning. It is probably true that even today there are many places where the textbook is the course in science and where learning consists largely of reading the text and reciting its contents back to the teacher. In spite of the recognized abuses of the textbook method, there is no doubt but that it will continue to be an important adjunct to learning in science classes for many years to come.

Properly used, the textbook may become a very important part of a course in science. When a single basal text is the only reference source, there is, of course, the danger that the pupils will come to think of the text as the only source of material and will thus have a distorted conception of its true value.

In many places sets of textbooks in the various science subjects are being provided. Rather than following a single text slavishly, many teachers are encouraging pupils to seek widely in several sources for the information that will help them solve their problems. This plan makes for better learning habits on the part of the pupil.

In recent years there have appeared on the market, in the various sciences, several texts which are based on problems. In these books many activities are suggested for aiding in the solution of the problems and usually references are given to other books dealing with the same problem. In this way a single basic text may be used to supply the pattern of development and other texts and references used in a supplementary way. In Chapter 8 further consideration is given to the problem of securing information from books.

The individual method. Under the impetus of the measurement movement, educators in general have become conscious of individual differences and have sought ways of providing for these in the classroom. Science teachers along with others have been active in devising schemes which would permit a student to progress through the work at his own rate. In most of these schemes the pupil has assumed the responsibility for his own learning, and this is a laudable point. It is, however, equally true that in many such plans the burden of administration has so increased that the teacher has become a mere checking clerk and bookkeeper. It should also be pointed out that when the individual scheme is used in the extreme, many socializing values of discussion and group work are lost.

Recently the extreme individual plan has been modified in most schools, and the trend now seems to be to start a group together on a given unit and then permit them to spread on the basis of their working rates through the unit. Those who complete the work first are encouraged to do supplementary work. When the majority of pupils have completed the work of the unit, the entire class is assembled for discussion and student reports. As variations of the individual method, the Dalton Plan, the Contract Plan, and the Project Method should be mentioned.

The small group plan. In this plan of teaching the teacher opens up a new area of investigation, and the class then organizes into small groups to investigate the various problems which have been defined.

Each group selects a group leader who becomes responsible to the teacher for the work of the group. The various groups then carry on whatever activities seem valuable for the solution of the problem at hand. From time to time the class is assembled by the teacher for general instructions or for hearing progress reports from the various groups. In the use of this plan, basic readings on the entire unit are generally required of all pupils. At the close of the unit the class assembles to hear the group reports, see important demonstrations, moving pictures, slides, etc., and take part in discussion and organization of the materials.

The development plan. In recent years there has been an increasing tendency in many schools to have the students share in setting the objectives of the course as well as in planning the ways and means by which problems will be solved. In such a plan the teacher helps the pupils define their problems, guides them in securing, organizing, and interpreting data, setting hypotheses, and reaching generalizations. In such a plan the subject matter usually becomes the means to the end of solving problems and many opportunities are presented for instructing the pupils in good techniques of problem solving. The latter part of this chapter is devoted to a general consideration of various aspects of this method.

Recent trends in method. In many places new plans of curriculum organization are being tried which alter teaching methods essentially. Among these schemes are the correlated curriculum and the integrated or core curriculum.

In the correlation scheme there is an attempt to teach related subjects in such a way as to make possible the consideration of various aspects of a unit or topic in several classes at the same time. For example, a class may be studying Community Health in social studies while at the same time Community Sanitation and Water Supply will be under consideration in the Science Class. This plan seeks to better orient the pupil without breaking down subject matter lines.

With the integration plan time is provided in the program for a class to meet for at least two consecutive periods.

Several teachers are made available, and a topic is investigated without reference to specialized content areas. When the direction of the work falls in the social area, the social studies teacher directs the work and when a science problem is encountered the science teacher takes over. In some places the work in English, music, art, and other subjects grows out of the integrated materials.

In both the correlated and integrated schemes the great danger is that integration will be achieved only in the paper outlines of the course. True integration is achieved only in the thinking of the individual.

The unit-problem method of instruction. The unit-problem concept of organizing and presenting science materials has become very popular in recent years as attested by many courses of study and textbooks which use it. In the use of this method the general pattern is to state the title of the unit as a broad problem or principle such as:

(1) How do we light our homes?
(2) How do we depend on plants for our food?
(3) How is the energy of heat put to work?
(4) How may energy be secured from atoms?

These broad problems are then broken down into smaller learning problems for purposes of instruction. Following is a break down of one major unit problem in physics.

UNIT PROBLEM. *What are the Principles Which Control the Simple Machines You Use?*

Problems to Solve.

1. How may force be measured?
2. What are levers and how are they used?
3. How are you helped by inclined planes?
4. How may simple machines be combined?

Teachers find that the unit-problem method of instruction is very flexible. Many of the techniques already discussed such as the lecture-demonstration, the textbook method, the laboratory method, and the individual method, may be used effectively in the same unit. Each method is used where it will produce the most effective learning.

Getting maximum results from the unit-problem technique. Any technique of teaching is at best only a framework or scaffolding through the use of which objectives may be reached more efficiently and effectively. In the final analysis the technique must be made to function by the carrying out of plans by teacher and pupil. The teacher must constantly remind himself that the end sought is the growth of the pupil and that the learning of content is only one of the means to this all important end. Thus the technique of instruction should never become such a fettish with the teacher as to obscure the needs of the pupil. It is necessary that teachers always be alert to select those learning experiences which will be most effective regardless of the teaching technique being used. Following is a selected list of the kinds of activities which may be useful in the "experience getting" or "assimilation" period of the learning cycle. These were taken from a list given by Pieper[4] in the *Thirty-First Yearbook* of the National Society for the Study of Education:

(1) Reading for various purposes such as (a) to gain perspective, (b) to find unsolved problems (c) to reproduce ideas (d) to make comparisons, (e) to gain facts for the solution of problems, (f) to select major ideas, (g) to find illustrations of generalized facts
(2) Interpreting diagrams or analytical drawings
(3) Interpreting maps
(4) Interpreting statistical tables
(5) Interpreting graphs
(6) Making analytical drawings
(7) Drawing from description
(8) Drawing from observation
(9) Making graphs of data
(10) Making tables of data
(11) Making maps
(12) Taking notes on reading
(13) Taking notes on a talk or lecture
(14) Manipulating in laboratory experimentation
(15) Observing manipulation in demonstration
(16) Observing and interpreting natural phenomena
(17) Observing and interpreting experimental phenomena
(18) Writing reports on experimentation

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[4] Pieper, Chas. J., "Science In the Seventh, Eighth, and Ninth Grades," *Thirty-First Yearbook* of the National Society for the Study of Education. 1932. Distributed by the University of Chicago Press.

(19) Organizing and writing compositions
(20) Organizing and presenting oral reports
(21) Preparing topical and statement outlines
(22) Preparing summaries
(23) Solving mathematical problems
(24) Making collections
(25) Constructing models, appliances, etc.
(26) Repairing appliances
(27) Interpreting construction and operation of appliances
(28) Evaluating popular notions or fallacies
(29) Making local surveys (home and community)
(30) Asking questions
(31) Preparing written questions to test knowledge gained
(32) Answering questions (oral and written) such as those (a) involving observation (b) involving pure memory (c) involving analysis, (d) involving selective recall, (e) involving the making of problems and questions (f) requiring a statement of causes or effects, (g) requiring the pupil to suggest or make applications of rules or principles in new situations, (h) requiring a decision, (i) requiring the pupil to compare two things in general, (j) requiring the pupil to give illustrations or examples, (k) requiring an evaluating recall when the basis is given, (l) requiring the pupil to state relationships, (m) requiring the pupil to compare two things on a single designated basis, (n) involving discussion (o) requiring the pupil to explain the use or meaning of some phrase or statement in a passage, (p) requiring the pupil to summarize some unit in the text, article read, or experiment performed, (q) involving new methods of procedure, (r) requiring the pupil to reorganize on a new basis facts learned in one organization, (s) requiring the pupil to give a brief outline, (t) involving aim—the authors' purpose in his selection or organization of material (u) requiring the pupil to criticise some statement as to adequacy, correctness, or relevancy, of a printed statement
(33) Evaluating social and civic problems on the basis of science knowledge
(34) Answering new-type examination questions
(35) Answering essay-type examination questions
(36) Keeping a science notebook
(37) Keeping a science scrapbook
(38) Helping in demonstration
(39) Taking charge of the bulletin board
(40) Consulting authorities
(41) Taking charge of class discussion
(42) Home experimentation

Types of errors made by pupils in learning science. The teacher must select learning experiences that will promote the growth of pupils. But the perfunctory performing of the activities within a given learning experience does not in itself insure maximum growth toward the outcomes sought. During the period of experience getting, or assimilation, in the learning cycle the teacher must take on the role of diagnostician and prescriber. She must become sensitive to the many types of errors made by children and have remedies available that may serve to erradicate the cause of error.

The range of types of errors made by pupils in learning science are almost infinite, especially if the teacher has set up a series of varied learning experiences calling for many different kinds of activity. There can be errors in securing evidence from experimental work, errors in interpreting evidence, errors in locating sources of information, errors in reading, errors in written work and many others. Beauchamp[5] has made a very useful classification of the causes of errors in the responses of pupils as follows:

(1) Misunderstanding the text or exercise
(2) Failure to determine method of procedure needed to secure the answer
(3) Failure to see the relation between experiments and subject-matter
(4) Tendency to memorize the text rather than to rationalize it
(5) Tendency to form conclusions without weighing the evidence
(6) Inability to distinguish between major and minor points
(7) Failure to use or interpret diagrams, tables, illustrations, and cross-section drawings
(8) Inability to visualize objects or processes from printed descriptions

Errors of the types listed and many others may be corrected by the alert teacher who is a keen observer of pupils as they work and who makes use of work periods for helping pupils to become aware of their errors. Many young teachers make the mistake of believing that doing an exercise for a pupil who has made an error is good teaching. A good rule to follow when a pupil has discovered an error is to demand some evidence of an attempt to correct the error on his own part before any help is given. Pupils soon learn how to lean on a teacher who will show them how to do an exercise. The most effective help is often a leading question or a suggestion as to where additional information may be found. Much poor teaching results from too much telling.

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[5] Beauchamp, W. L., Mayfield, J. C., and West, J. Y., *Teachers Guidebook*, Scott-Foresman and Co., Chicago, 1941.

Techniques for Developing Scientific Attitudes

Problem solving in all of its elements is closely associated with a group of attitudes or mind sets which are important as outcomes of instruction in science. One analysis listing certain of these attitudes was proposed in Chapter 5. Here some of the techniques that have been used for developing scientific attitudes will be reviewed.

What the research shows. The studies of Caldwell and Lundeen[6] seem to reveal that pupils in the junior high school possess unfounded beliefs about natural phenomena to a marked degree and, most important, that these beliefs influence the behavior reactions of the young people.

Carrying on independent investigations Wessell[7] and Lichtenstein[8] found that direct teaching failed to produce important changes in pupils' attitudes. Each of these investigators suggests that uncontrolled out-of-school experiences and such factors as maturation, are very important in the development of the attitudes held by young people.

A pioneer study by Curtis[9] and more recent investigations by Blair and Goodson[10] and by Vicklund[11] seem to show that direct teaching does modify the attitudes of young people. The fact that there is some conflict in the present evidence concerning teaching scientific attitudes in science should lead us to use the best known methods in the classroom until further research information becomes available.

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[6] Caldwell, Otis W., and Lundeen, Gerhard, "A Summary of Investigations Regarding Superstitions and Unfounded Beliefs." *Science Education* XX February 1936.

[7] Wessell, George, "Measuring the Contribution of the Ninth-Grade General Science Course to the Development of Scientific Attitudes." *Science Education,* XXV, November 1941.

[8] Lichtenstein, Arthur, "The Effect of Teaching Stress Upon an Attitude." *Science Education* XIX, April 1935.

[9] Curtis, F. D., "Some Values Derived from Extensive Reading in General Science." Teachers College, Columbia University, New York, 1924.

[10] Blair, Glenn M., and Goodson, Max R., "Development of Scientific Thinking." *School Review* XLVII, November, 1939.

[11] Vicklund, C. U., "The Elimination of Superstitions in Junior High School Science." *Science Education,* XXIV, February, 1940.

When we study the behavior of people at large, and note the extent to which action is based upon emotional rather than upon reasoned judgment, it seems safe to assume that whatever can be done to associate behavior with desirable attitudes in science teaching is of value. A few techniques that have been used will be reviewed.

The use of wide reading. The study made by Curtis[12] and cited above, gave rather clear evidence that pupils who engage in wide reading in general science develop scientific attitudes more than those who study only a single text. This would seem to indicate that whenever it is possible, the teacher should supplement the text book with readings on the problem under consideration. Much of the content of science is intimately bound up with facinating historical and biographical incidents which make excellent material for supplementary readings and reports. Many of these incidents relate how the masters of science worked and what attitudes motivated their action. These should become a part of every course in science. If the references are not available for general reading the teacher might use a period for an inspirational talk on the life of some scientist concerned with the problem being studied.

The study of superstitions and unfounded beliefs. We assume that we live in an enlightened age free from the influence of superstition. Pupils may be shown the fallacy of this assumption by making a survey of the magazines on astrology found on the newsstands or the horoscopes published in many widely read newspapers and on sale at drug stores. Time spent in analyzing horoscopes and articles in magazines on astrology will prove interesting and perhaps valuable in acquainting pupils with the problem.

Some teachers have found pupils very interested in making a survey of superstitions and unfounded beliefs. Such a study will provide a great deal of material for interesting class discussion. Just talking about scientific attitudes may not change the behavior pattern of young people. In some cases teachers have brought a ladder into the classroom and had an activity to see how many pupils would walk under it. Another suggestion is to have each pupil bring a small mirror and see how many will actually break it before the class. While these may have the appearance of stunts they do have elements of a direct attack upon the problem of attitudes.

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[12] Curtis, F. D., *loc. cit.*

The use of planned exercises. Newspapers and magazines are excellent sources of materials that may be collected and used for building planned exercises on attitudes. In one such file kept for a number of years by the writer may be found pictures of people walking under a ladder, the advertisement of an oil company showing an oil prospector using a divining rod, and many other such things. This material is used over and over both for bulletin board and for direct teaching.

Some textbooks in general science and biology provide exercises devoted to practice in the use of desirable attitudes. The following exercise is illustrative:

> Some people believe that if a bird happens to fly into the house through an open door or window that a death is certain to occur in the family unless something is done to thwart the superstitions influence. Which of the following statements do you think would most nearly represent the reactions of a person who has scientific training?
>
> (a) There is probably no foundation for the belief.
> (b) For some people the belief is probably well founded.
> (c) The belief is silly.
> (d) There can be little doubt but that the belief is well founded.
> (e) While I do not believe in this, yet I am disturbed when a bird flies into the house.

Following is a lesson plan that has been used by a teacher of general science in the direct attack upon one of the scientific attitudes.[13]

Purpose of the lesson was to teach a scientific attitude: A scientist is open-minded and waits for further evidence before he formulates a definite conclusion.

Teacher directed activities	*Pupil responses*
(1) Of what larger unit is the earth a part?	(1) The solar system.
(2) What are the various bodies of the solar system?	(2) The sun, planets, satellites, meteors, and meteorites.

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[13] This lesson plan was prepared by Miss Edith Selberg of the Colorado State College of Education, Greeley, Col.

Teacher directed activities	*Pupil responses*
(3) How are these bodies arranged in the solar system?	(3) The sun is the center of the solar system. The planets revolve around the sun and are arranged in the following order: Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, Neptune, and Pluto.
(4) Why is the sun found at the center of the solar system?	(4) The sun was the first body and the planets were originally a part of it.
(5) How do the planets move around the sun?	(5) The diagrams show that they move in the same direction.
(6) How do the satellites move?	(6) They revolve about the planets.
(7) How do the planets vary in the number of satellites which revolve about them?	(7) The earth has one, Mars two, Jupiter and Saturn many, Venus and Mercury none. The larger planets have many and the smaller ones few or none.
(8) Have you ever wondered why the planets move as they do? Why the sun remains at the center of the solar system? Why the other bodies move as they do?	
(9) What group of workers can give us the best answers to these questions?	(9) The astronomers.
(10) What problem would the astronomer have to find out before he could arrive at any answer?	(10) (1) He would have to find out how the solar system was formed. (2) He would have to find out why the bodies move as they do and why they are found at certain distances from the sun.
(11) What method would the astronomer use in securing information that can answer the problem—How was the solar system formed?	(11) He would (1) set up a problem; (2) gather information by studying the heavens through the telescopes; (3) arrange and record his data; (4) form a tentative conclusion, summary, or hypothesis; (5) formulate a tested conclusion.

Teacher directed activities	*Pupil responses*
(12) Through the above method the astronomers have given the world several explanations or hypotheses. On the following mimeographed sheets several hypotheses are stated, together with the evidence used as a basis for the explanations. Just how far has the astronomer answered the problem?	(12) He has only formulated a tentative answer.
(13) How can he test his hypotheses?	(13) He can check it by further observations and by the opinions of other scientists.
(14) What is the problem which you should keep in mind as you read? As you read, decide whether you will accept any one or all of the hypotheses. Now that you have finished your reading . . .	(14) How was the solar system formed? (Period of reading.)
(15) Which of the hypotheses will you accept?	(15) I would accept the planetesimal hypothesis because it seems to have the best evidence. Chamberlain and Moulton succeeded in obtaining photographs of the nebulae which may show how the solar system was formed.
(16) Why was the nebular hypothesis accepted for nearly a century and a half by thinking individuals?	(16) Because it was the only explanation which was based on evidence that was available at that time.
(17) Why was it later disproven?	(17) When the telescopes were perfected many of La Place's ideas were found to be incorrect.
(18) If the nebular hypothesis were the only explanation which we would have today would you accept it? Why?	(18) Yes, if there wasn't any other and it seemed reasonable. Because it is based on data and comes from an expert in the field.
(19) How long would you accept or hold the hypothesis?	(19) Until a better explanation is given which is based on accurate data.

Teacher directed activities	*Pupil responses*
(20) Why wouldn't you accept Jeans and Jeffrey's hypothesis?	(20) Because there isn't enough evidence to support it, it is so new.
(21) Would you reject it entirely?	(21) No, because the men are trained scientists in their field.
(22) Would it be possible for Jeans and Jeffrey's hypothesis to replace the planetesimal hypothesis?	(22) Yes, if they succeed in obtaining better and more data.
(23) What should be our attitude toward tentative explanations which the scientists give us?	(23) We would accept it until we have information which shows that it is incorrect.
(24) What important idea has the lesson taught you?	(24) A hypothesis should be accepted until sufficient information is available.
(25) In what everyday situations that you can mention would it be important for you not to jump to conclusions but maintain an open mind until you have proof?	(25) (1) In answering or arriving at conclusions to problems in the unit. (2) In deciding whether we liked certain people or certain things. (3) Our likes and dislikes may be biased by what others say.

The use of the laboratory period for developing desirable attitudes. The laboratory period in science offers many opportunities for practicing good attitudes. The teacher should see to it that the problem of the experiment is clearly stated, that hypotheses on the solution are presented, and plans for testing the hypotheses are made. In this discussion the matter of control and experimental factors should be brought out. After the experiment has been performed the evidence should be discussed and interpreted. The pupils should decide whether there is sufficient evidence upon which to base a conclusion or if more evidence is needed. They must be taught to suspend judgment where this is necessary.

The influence of the teacher and the atmosphere of the classroom in developing desirable attitudes. Perhaps the greatest force at present in the development of desirable attitudes is a teacher who practices them day after day in his classroom. The atmosphere of such a classroom will be charged with a spirit of friendly criticism of procedures, data, hypotheses, and conclusions. It will encourage an intelligent questioning of authority and maintain a skepticism for reported evidence. Emotional and wishful thinking will be questioned, and prejudice and intolerance will find no place. Facts and assumptions will be clearly distinguished, and hypotheses modified in the light of new evidence. If such an atmosphere could be maintained in our science classrooms we could go a long way toward inculcating desirable attitudes even without the benefit of test results.

Techniques For Developing Appreciations

A list of the appreciations to which science may make a contribution were given in Chapter 5. Some of the techniques which may be used in developing such appreciations will be considered here.

At the outset it should be noted that an appreciation of anything comes only with understanding, and that teachers should be alert to develop those understandings which are basic to appreciations. For example, a pupil can come to appreciate man's place in the universe only as he develops understanding for man's relationship to the environment in which he lives, the dependence of this environment on the sun, and the place of the sun in the universe. Thus it would seem that appreciations are to some extent long range goals, the foundations for which are begun down in the elementary school. The experiences on successive levels serve to enlarge and enhance the meaning and understanding of the appreciation.

The development of appreciations in young people will naturally vary in method with the level of instruction. In the early years of the junior high school, students are interested in stories of adventure and romance, while later on their interests shift as they read the historical materials to see how some of the great scientists worked, what their problems were, and how they solved them. In English classes they are reading *Moby Dick* and *Treasure Island*. They are thrilled by the romantic adventures so vividly told by Jules Vernes. This interest, properly directed, may become a powerful motivating factor for science study at this level.[14] There is so much worthwhile material in the field of discovery and invention upon which to draw that hardly a problem will be raised which will not have some interesting historical antecedent.

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[14] A splendid source of such material for science is the book *Heroes of Science,* by Colton and Jaffe, Little, Brown and Co., Boston, 1934.

The story of Davy and the discovery of the safety lamp, of Robert Koch and the discovery of the cause of anthrax, may be used to show the young people how the scientist solves his problems. The fields of astronomy, physics, chemistry, biology, and geology are all filled with interesting and worthwhile materials of this type which should become a part of the background of every boy and girl who studies science. If the student is directed to such books as the *Life of Pasteur* by Vallery-Radot, or the *Microbe Hunters,* or *The Hunger Fighters* by Paul deKruif, it is possible for him to study the careful and systematic approach used by scientists in solving their problems.

In connection with this aspect of learning science, the teacher may prepare a series of analysis sheets based on certain readings which will bring out for the student the important points as related to problem-solving techniques.

In the science courses which come late in the high school it will be found that historical and biographical materials may be used for giving perspective and setting to modern problems of science which have certain social implications. For example, in the study of many problems of transportation or communication, a knowledge of the historical and biographical backgrounds will give meaning and enrichment to the solution.

Appreciations must be taught for directly and sought by the learner if they are to be realized as outcomes.

Techniques for Developing Interests

The following discussion of techniques for developing interests has been taken from the *Forty-Sixth Yearbook* of the National Society for the Study of Education.[15] It was originally prepared by one of the authors.

> There has been considerable research devoted to the problem of the science interests which children have at different ages. There has been

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[15] "Science Education In American Schools." The *Forty-Sixth Yearbook* of the National Society for the Study of Education. The University of Chicago Press. Chicago, 1946, pp. 178–180.

much less study of the problem of methods of stimulating and developing abiding interests in science. This latter problem is a very real one. It is the problem of this section. It is so important that it may spell the success of a given lesson.

Many teachers have the notion that materials to be learned must in some way be made "rose-colored," "glamorized," or "sugar coated" to enlist the interest of pupils. This fact is evident when teachers go to extremes in opportunistic teaching or in the use of spectacular experiments or demonstrations. Once the idea of expectancy for this type of science teaching is set up, it may prove to work out in reverse, for the learner's interest may fall to lower levels if each day's lesson fails to produce something of the bizarre.

This is not to argue against the occasional use of unusual demonstrations in science teaching or the use of unique procedures at those levels of learning where there is inherent interest in the romantic and adventurous aspects of the subject. The real problem exists where these methods are used to the exclusion of all others.

Somewhat in contrast to the methods of sustaining interest mentioned above is the idea that satisfying learning in itself may be dramatic and challenging to the interest of the learner. Every teacher has, at some time, had the experience of a drab and routine lesson being suddenly transformed into a thrilling experience with pupil interest at a very high level. Perhaps it is more than we may expect that each day's work can be of this nature.

A class in general science was showing only average interest in the study of bacteria cultures as related to a problem in health until a pupil raised the question of the dangers of kissing. The next day another pupil brought in pictures of cultures taken from the lips of college men and women. The class interest was high at once. They wanted to try the experiments. Several members of the class gave up a movie on Saturday to come to school and prepare more culture plates for the experiment. The experiments were tried and the days while the plates were incubating were "red letter" days as far as pupil interest was concerned. When problems become real to young people their interest in the solution will always follow.

Problem-solving methods offer many opportunities for enlisting student interest. Defining problems, proposing hypotheses, planning controlled experiments, testing hypotheses, evaluating data, and others, are cooperative classroom undertakings which go a long way toward keeping student interest at a high pitch. Once the interest of the pupil is aroused the questions of application and effort disappear.

The idea that science may hold both vocational and avocational interests for young people was pointed out in Chapter 2. In fostering these interests the science club is perhaps the most fruitful device. In the larger city schools this may be a diversified activity in that there will be many clubs related to specialized science interest, such as radio club, a photography club, or a chemistry club. However, in the smaller high schools the single science club must be the rule because of the lack of trained faculty personnel for sponsoring more than one.

Techniques for Developing the Skills of Problem Solving

Setting the problem. Children learn problem-solving techniques by solving problems which are both interesting and worthwhile for them. If students are to have genuine interest in the solution of problems, they should have some opportunity to share in the stating of the problems within a given area of adjustment and in planning their solution. The setting of the problems for study over a given period is very vital to the success of the learning and should therefore be planned carefully by the teacher. A cooperative approach may be used in which the teacher opens up the field for investigation, draws upon the experiences of pupils to suggest places where problems might exist, and then encourages them to state the problems in their own words.

Adjustment to problems arising out of the environment of pupils regularly demands some change of behavior. The expected change in behavior may often be expressed in verb form. The resourceful teacher can find a wide variety of verbs to use in stating worthwhile problems. Following are a few such verbs, selected at random, around which problems from many areas could well be stated:[16]

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[16] This list is based on one prepared by Charles J. Pieper, New York University and adapted from page 168 of the *Forty-Sixth Yearbook* of the National Society for the Study of Education.

avoid
build
care for
cause
change
collect
conserve
control
destroy
devise
feed
generate
grow
identify
improve
inspect
maintain
make
manipulate
measure
obtain
operate
organize
perform
plant
predict
prepare
provide
purify
rear
recognize
regulate
remove
repair
rid
safeguard
select
supply
take apart
train
transfer
transmit
use
work

For example:

How does one *avoid* a contagious disease?
How may harmful bacteria be *destroyed?*
How may we *identify* harmful mosquitoes?
How do communities *obtain* pure water?

Another method for setting problems may be used either with the one suggested above or independently. In this procedure the teacher does demonstrations, cites experiences, etc., in such a way as to raise questions and problems which are then stated by the students.

While problems are being set there is an excellent opportunity for the teacher to bring out certain characteristics of a good problem such as:

(1) The problem should be at or near the maturity level of the pupil.
(2) The problem should be stated clearly and concisely.
(3) The problem should not be too broad and inclusive.
(4) The problem should be properly delimited.
(5) The problem should in general be possible of solution with materials at hand.
(6) The problem should be worth while for the learner.
(7) The problem should be a part of an enlarging understanding.

Students should be taught to state problems in clear concise English. This is an excellent opportunity for the science teacher to aid in developing good expression skills. Students may be asked to write down their statement of problems. These may be read in class and critically discussed in the light of some such criteria as are suggested above.

This preliminary period of selecting and stating problems is an excellent time for the teacher to develop a greater sensitivity to problems in students. This is a difficult thing to develop, but may be aided by encouraging students to use their senses in getting impressions; to be analytical of experiences; to be questioning readers; to think about things and experiences in their environment.

After problems have been selected and stated, it is essential that time be spent in suggesting methods of solution, sources of information, etc.

The following lesson plan[17] has been used in helping pupils to learn how to state a problem.

LESSON 1—Teaching Pupils How to State a Problem

1. State some problems that you would be interested in studying in science class this year.
2. The following are written on the blackboard for analysis as suggested by pupils from their papers:
   (1) What is astronomy and how does it help man?
   (2) Electricity.
   (3) The facts about electricity, how to control it and how it is generated.
   (4) The facts about plants and animals and how to control them.
   (5) To study astronomy.
   (6) How does a telegraph instrument work?
   (7) To find batteries that will make electrical instruments work.
3. From the above statements it is noticed that many individuals have different ideas as to the way in which a problem should be stated. The above problems should be analyzed and the one which represents the best of our combined thinking may be selected.
4. What are the criticisms on No. 1?
   (a) It states two ideas. A problem should state one important idea.
   (b) The first part of the sentence calls for a definition and can be answered in a few words.
   (c) The problem is too broad and not specific enough for us.
5. Criticize No. 2.
   (a) It is the statement of a single word.
   (b) It doesn't state what you want to know about electricity.
   (c) It should be stated in the form of a question.
6. Criticize No. 3.
   (a) It contains two ideas which may be stated as problems:
   How is electricity generated?
   How is electricty controlled?

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[17] This lesson plan was prepared and used by Miss Edith Selberg of the Colorado State College of Education, Greeley, Col.

    (b) The first part is indefinite.
7. Are there any other statements which are similar to No. 3?
    (a) No. 4.
8. Can No. 5 be accepted? Why?
    (a) No, it is indefinite and too broad.
9. Can No. 6 be accepted? Why?
    (a) Yes, because it is definite.
10. Does it satisfy other criteria? If so, which ones?
    (a) It is stated as a question.
    (b) It is specific and definite.
    (c) It requires thought and gathering of ideas.
11. Which of the criteria does No. 7 satisfy?
    (a) The second and a little of the third.
    (b) As stated, the person is going out to locate them rather than experimentating or studying about them.
12. Write the "criteria" for the statement of a problem in your notebook. This will be used when you formulate your individual study guides.
13. In the light of the criteria accepted, rewrite your own statements at the bottom of the paper on which you wrote the first draft of your problems.

Lesson 1—Seeing and stating a problem.

Before a problem can be solved, one must be aware of a problem specifically so that it will direct learning.

The following situations will provide drill for seeing and stating a problem. It involves the use of action phenomena to direct the learner's observation.

Teacher directed activities	*Pupil responses*
1. Siphon is constructed	1. (a) Students watch its operation.
(a) What problem is suggested by the operation of this device?	Why does water run uphill? How does air pressure operate in the siphon? Why does the water run from one beaker to the other? What is it used for?
(b) Which of the problems is best suggested by the experiment? Why?	(b) "B" is the best.
(c) But can you see the air pressure in operation?	(c) No.
(d) Which problem is suggested by the action?	(d) "C" is suggested because that involves the action which is shown.

Teacher directed activities	*Pupil responses*
2. A second experiment is one in which a coiled wire is attached to a galvanometer and a bar magnet moved forth and back through the coil.	2. (a) "Why does the needle in the galvanometer move?" Because it is the action which results from the movement of the magnet.
(a) What is the problem that is suggested? Why?	(b) Why is the magnet moved forth and back? This also shows action.
(b) Which is the more significant problem?	(c) The first one.
3. A third experiment is one in which water in a flask has been boiled until the air has been expelled by the steam. The flask is stoppered and placed in an inverted position in the sink. Cold water is poured slowly over the bottom.	3. Why water is boiling?
(a) What do you observe?	(a) Why does the water boil in the flask when cold water is poured over it?
(b) What is the problem?	(b) Will cold water do the same?
(c) Which one specifically suggests the main problem of the experiment? Why?	(c) Why did you boil the water first? (d) The first one, because that represents the action of the experiment.

Analyzing problems for solution. The analysis of a problem is an essential step toward securing information bearing on it and therefore its ultimate solution. When the single major factor in a problem situation has been isolated, further analysis should reveal the key words or ideas in the situation. For example, let us assume that a problem for a physics class has been defined as follows:

How is mechanical energy transformed into electrical energy at our local power station?

There are in this problem both primary and secondary key words and phrases which when identified may furnish clues to the further study of the problem. The primary key words here are *"mechanical energy," "transformed,"* and *"electrical energy."* The secondary key phrase is *"local power station."* The primary key words might lead at once to places for securing book information, while the secondary phrase might easily suggest consulting some expert at the local power station or even planning a field trip for collecting evidence.

Some teachers prefer to have pupils underline or otherwise mark the key words and phrases in the problem. At this point it is very important that every pupil in the class know the meaning of all words in the problem and particularly the meaning of the key words. This is one place in science teaching where the teacher can be of great assistance to the pupil in helping him to learn the technical vocabulary of the subject. This perhaps, is a good place to teach the use of the glossary in the textbook or the dictionary. When the key words in a problem have been defined a long step has been taken toward better insight into the perplexity involved.

Studying the problem for all possible clues and facts bearing upon it. Chapter 7 is devoted to a detailed consideration of the important aspects of collecting evidence on the solution of problems. Both the skills involved and the variety of devices for developing them are discussed. At this point only a few suggestions will be made regarding useful techniques for developing these skills of problem solving.

The alert teacher will find in this aspect of the problem-solving objective many opportunities for guiding pupils in the development of a variety of skills and techniques. In collecting evidence bearing on the solution of a problem the pupil will be called upon to use many devices such as general references, textbooks, interviews, field trips, experiments, models, graphs, moving pictures, charts and the like. Each of these devices calls for a specific technique or a special set of skills for which the pupil must have guidance and instruction.

The following two classroom incidents[18] indicate the importance of emphasizing *conflicting evidence* and *sufficient evidence* when experiments are being used as a source of information.

1. In studying the telephone as one device for modern communication, it was found that the telephone receiver contained a permanent (horseshoe) magnet, on the ends of which were mounted electromagnets. After removing the cap from the end of the receiver, the diaphragm was held above and away from the end of the receiver, and

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[18] These incidents were related by Mr. Gaylord C. Montgomery of the John Burroughs School, St. Louis, Mo.

then dropped. It moved to about the proper position, then "stuck" there. An explanation of what they had observed was requested from the class. The reply was: "The magnet attracted and held the diaphragm." "What kind of magnet is contained in the receiver?" "An electromagnet." "What evidence have you?" The receiver which I had carried half way across the room and to which was attached about thirty inches of cord, free at one end, was handed to the pupil. "I can see two cores, each wrapped with a spool of small wire." "What is attached to the other end of the wire?" "Nothing." The concept of conflicting evidence began to develop. "If an electromagnet is attracting and holding the diaphragm, what must flow through the coils?" "Electricity." "Where is the electricity coming from?" "Where is its source?" "There isn't any."

2. The foundation of modern electricity was laid by two Italian physicists, Alessandro Volta and Luigi Galvani. At the end of the eighteenth century Galvani discovered the existence of the electric current, which passes through media called conductors. His researches led Volta to invent the first electric cell, later called the voltaic cell, which is now the foundation of our electric batteries. The ninth-grade pupils had learned, through laboratory experiences, of two sources of electricity: friction, and the transformation of chemical energy into electrical energy by the ammonium chloride cell. They had examined worn-out dry cells, sawed lengthwise, and could recite with reasonable accuracy the principle of the latter: "Electricity can be secured from chemical energy whenever two unlike substances are dipped in solution, provided one of them is acted upon more rapidly by the solution." The day following the development of this concept, the class was asked if any pupil had a dime that he or she would exchange for two nickels. Taking the dime obtained, a piece of wet toweling soaked in salt-water was placed between the dime and a penny and held before the class. The coins thus arranged were handed to the nearest pupil and she was requested to walk down the aisle holding them so that her classmates could make observations at close range. "What name may be applied to this device?" was asked of the class. In a moment hands were waving and the general opinion expressed was to the effect that the girl held a "wet cell." "What is your evidence?" "Wires held to the coins with the other ends of the wires attached to the terminals of a galvanometer would, perhaps, deflect the needle." The galvanometer was supplied and the wires held as described, then reversed with respect to the coins, and the needle thus deflected in each direction. "Have we sufficient evidence of a wet cell?" The suggestion was proposed that a sufficiently large number of such coins, alternately placed, would ring a small demonstration electric bell. This was provided while the pupils emptied their pockets of pennies

and dimes and the bell was run vigorously. Thus, further evidence substantiated the conclusion.

Interpreting evidence and drawing inferences in the solution of problems. In recent years there has been an increasing desire on the part of many teachers to include this aspect of reflective thinking among the desirable outcomes toward which their teaching might be directed. It should be clear at the outset that this aspect of problem-solving behavior is not a specific but is a complex of many skills and abilities. And therefore, in approaching the question of how children may be taught to make reasonable interpretations of data, it is essential to break the large area down into its simpler abilities and then to consider ways and means of setting classroom situations for developing these. Such an analysis of the general ability to interpret data might involve, in part, the following more specific abilities:

(1) The ability to analyze.
(2) The ability to distinguish between fact and assumption.
(3) The ability to discern consistencies and inconsistencies in data.
(4) The ability to recognize fundamental assumptions underlying data.
(5) The ability to generalize and establish principles in the light of data.
(6) The ability to establish causes on the basis of observed effects.
(7) The ability to predict effects on the basis of established causes.
(8) The ability to evaluate data.
    (a) Accuracy
    (b) Adequacy

In developing effective skills in students for use in the interpretation of data, it is desirable that the learning and evaluation procedures should parallel each other. For the learning process should begin first with evaluation in the form of an inventory to discover which of the specific skills are deficient, and should end with evaluation to reveal the extent to which the learning has enhanced the skills. As Raths[19] has clearly put this point "Any 'interpreting' situations, whether 'teaching' or 'testing', should give students opportunities to reveal whether or not they possess these skills."

With the above analysis a teacher may study the learning situations which are to be used in the solution of a problem and so plan them that a good selection of the skills and abilities will be practiced by the student during the solution of the problems.

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[19] Raths, Louis, "Appraising Certain Aspects of Student Achievement," *Thirty-Seventh Yearbook* of the National Society for the Study of Education, Part I, Guidance in Educational Institutions, Chapter III, 1938.

Certain aspects of selecting evidence will of necessity overlap the step of arranging the data. For example, it is not possible to arrange data for adequate study unless it has been analyzed at least to some degree. It is possible to begin at an early level in science, certainly by the time a student enters the junior high school, to give considerable practice in analyzing data from almost any problem situation and then to ask the students to list the inferences to be drawn from the evidence. For example, in the solution of a problem dealing with the nature of air, the following development is possible:

(1) A drinking glass is pushed down over a cork floating in a basin of water.
(2) Water is allowed to gurgle from a small-necked bottle which has been inverted.
(3) An attempt is made to pour water into a jar which has been stoppered with a one-hole stopper carrying a funnel.

The students are asked to observe carefully what happens in each case and list exactly what they see. After data has been arranged on the blackboard, the teacher asks the student to analyze the evidence to see if there are any similarities in the results, then to note any differences. Following the analysis of the data, the students list all of the inferences which may be drawn. These are then checked to see whether the data will support them. If any are found that conflict with the data they are discarded. Those which seem to be reasonable in the light of the data are then subjected to further tests, usually proposed by the pupils. Finally it is possible for them, on the basis of tested evidence, to arrive at the statement that air will occupy space.

This exercise has given practice in careful observation, recording, arranging, and evaluating evidence as well as in the proposing of hypotheses, the testing of hypotheses, and in stating a principle. The next step in the series is to give pupils situations in which the principle is applied in other ways.

In the solution of a problem related to the work of vitamins a student might be confronted with a situation of the following nature:

Health authorities sent to the Philippine Islands following the Spanish-American War found many people ill of beriberi. An investigation revealed that the diet of many of these people consisted of rice from which the outside hulls had been removed. It was further found that when these people were fed with rice which contained the outside hulls, the health of those with beriberi improved almost at once.

The students are asked to write down the inferences which may be drawn from such evidence and to propose ways of testing out these inferences.

A problem related to why a person pitches forward in a car that has suddenly stopped or is thrown backward in a car suddenly started, might lead a student to infer a cause or reason for such situations as the following:

(1) A person tends to feel lighter for a moment when an elevator suddenly starts downward, and heavier for a moment when it suddenly starts upward.
(2) A heavy hammer or weight is often placed behind a springy board into which a nail is to be driven.
(3) Rugs are shaken to remove dust and dirt.

Again, a student might be asked in a certain situation to predict some of the effects if the force of gravity were suddenly to disappear, or to predict whether an acid which has dissolved a piece of magnetized iron will be magnetic.

Evidence that is presented in some graphical form offers excellent material for giving students experience in interpreting data. Among such may be listed consumer statistics, health graphs, accident graphs, and many others.

Selecting and testing the most likely hypothesis. Parts of this section have been adapted from the *Forty-Sixth Yearbook* of the National Society of Education,[20] for which it was originally prepared by one of the authors.

Teaching to develop the skills of problem solving is a time-consuming process and, if it is used for this purpose, something must be sacrificed in the amount of content covered in a given period of time. The slow and careful guidance that a teacher must use in leading a class from the formulation of a certain group of hypotheses, through the steps of selection, testing, and rejecting, and finally to a conclusion, may require several class periods. In the same time much more ground could have been covered by the usual classroom procedures.

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[20] *Ibid.*, "Science Education In American Schools," Chap. XII.

Selecting the most likely one of several hypotheses for the solution of a given problem may involve several special skills, such as the analysis and interpretation of data, judging the pertinency of the data for the immediate problem, and checking the data against recognized authorities.

A class in general science had been studying the unit on air and air pressure. Toward the close of the study a problem about the workings of a vacuum cleaner was stated as follows: How is dirt picked up by a vacuum cleaner? The teacher asked the class to give the best explanation. Several hypotheses were proposed but after careful consideration all were rejected except two:

(1) The dirt is pulled into the bag.
(2) The dirt is pushed into the bag.

It seemed that these were the two most likely hypotheses. At this point the period ended, the teacher asked each pupil to devise tests that might be used to check these hypotheses so that the better one might be selected.

TESTING THE HYPOTHESIS BY EXPERIMENTAL OR OTHER MEANS

At the next meeting of the class several clever experiments were proposed and suitable controls were discussed. Some of the proposed experiments were:

(1) Measure the pressure in front of and just behind the fan while the fan is turning.
(2) Remove the bag and trace the air with smoke.
(3) Observe the motion of flour when it is picked up by the cleaner.
(4) Observe the bag behind the fan when the motor is started.

A vacuum sweeper and a small rug were brought into the classroom and several of the experiments were tried out. From these tests the pupils were able to prove the hypothesis—that the dirt was pushed into the bag by the air pressure outside.

This situation is not novel; it is, in fact, quite commonplace and could be found in almost any classroom when air pressure is being studied.

Space will permit only one other example of a situation that might be used for proposing, selecting, and testing hypotheses: A girl was using a short, narrow rubber tube to siphon the water from a heavy aquarium. The water was flowing too slowly. She observed that the water was very dirty.

The problem: How can the siphoning be speeded up?

Evaluating the data. Check the items given in the following list that are important in the solution of the problem.

(a) The tube was too short.
(b) The aquarium was heavy.
(c) The water was dirty.
(d) The tube was too narrow.
(e) The tube was not filled with water.
(f) The tube had a hole in it.

Hypotheses. The siphon could have been speeded up by:

(a) Using a longer tube.
(b) Lowering the outlet of the tube.
(c) Using a glass tube of the same size and length.
(d) Using clear water.
(e) Using a larger tube.

With these or other hypotheses before a class, the time is ripe for using the skills of selecting the most tenable hypothesis, for proposing controlled experiments for testing, and finally for the testing itself. Such experiences are dramatic for the pupil and are filled with thrill and suspense.

To attain many of the outcomes discussed in this chapter, it is not necessary to abandon the content of science courses as now organized and taught and swing completely to the views expressed in such reports as the one published by the Science Committee of the Commission on the Secondary School Curriculum of the Progressive Educational Association![21] Much of the present content of high-school science will lend itself, with a slight shift of approach and emphasis, to giving practice in such abilities as those involved in proposing and testing hypotheses. The greatest need is for teachers to develop an alertness to the potentialities in this direction in present materials. An example will illustrate the point.

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[21] "Science in General Education." The Science Committee of the Commission on the Secondary School Curriculum of the Progressive Education, Appleton-Century Co., New York, 1938.

A class in physics had been working on the principle of the siphon. Demonstrations and readings had been done in the usual manner, and the class had discussed the applications of the principle. Someone raised a question as to the speed of flow of the siphon and the factors which controlled it. The teacher turned the problem to the class and through discussion several factors which might affect the flow were proposed. Some of those proposed were fluid friction, viscosity of liquid, size of tube, difference of level, density of liquid, etc. In discussing the way in which each of these factors affected the flow, several hypotheses were suggested. The class decided that the best way to discover if and how these factors affected the flow of the siphon would be to carry on some experimentation. Groups were formed, with each group taking one of the proposed hypotheses for testing. Each group then devised an experiment and designed simple equipment to control all factors except the experimental variable.

The students went to work with more interest and enthusiasm than the instructor had seen in a long teaching experience. The next day brought forth plans of all sorts which were discussed pro and con in the groups and tried out in a preliminary way. The instructor was amazed at the resourcefulness of proposals and the uniqueness of design for some of the experiments.

The experiments were performed under varying conditions, and finally the evidence was presented to the class by each group in turn. In several instances the results reported were seriously questioned on the basis of inadequate controls or careless manipulation. This prompted a period of checking results, and other individuals designing equipment and testing out certain doubted evidence. In one or two instances it was necessary to modify the evidence as first reported.

In all, this work on the siphon consumed nearly two and a half weeks. A long time in light of the fact that ordinarily not more than one or two class periods are given to it in the physics course. And yet the returns from that period paid good dividends in added interest in the course and in later tendencies on the part of many of the students to approach their work more scientifically. Throughout the remainder of the year, they frequently requested the use of a similar method in attacking subsequent problems.

In such an approach the ground to be covered has to be sacrificed to the accomplishment of certain other outcomes, and this is not always possible or wise, especially where some of the students are preparing for College Entrance Examinations. And yet it would seem from experience that several such experiences spread over the year's work would pay dividends even to the point of making the remaining work more vital.

Drawing conclusions and making generalizations. This step in the problem-solving process follows closely from, and is intimately related to, the preceding step of testing hypotheses. In fact it often happens that the tested hypotheses is the conclusion to be reached. Some of the following abilities may be useful in the effective carrying out of this step:

(1) Competency of expression.
(2) Judging the consistency of the generalizations in the light of the hypothesis and other established evidence.
(3) Establishing principles and generalizations in the light of the hypothesis and other tested evidence.
(4) The ability to classify conclusions under a generalization.

The illustrations cited above seem to show how classroom situations in science can be so handled as to give practice in drawing conclusions from tested evidence. Many of the experiments now performed as a part of the courses in general science, biology, chemistry, and physics offer untold opportunities for giving practice in drawing valid and logical conclusions from evidence. Science teachers should use the data of experiments more as a basis of class discussion. Also, demonstrations should be used more to furnish evidence from which conclusions may be drawn.

It is quite true that the solutions of all problems do not lead to new generalizations. Often a conclusion merely supports another generalization. In the use of this ability, however, it is essential that students be trained in classifying conclusions that do support established generalizations, and in the forming of new generalizations when they do not support those already formulated.

The assumption should not be made that the development of problem-solving abilities works against the building up of those basic concepts and generalizations which form the warp and woof of specialized science and their social implications. Quite the contrary. In the solution of problems which are worthwhile to him, the learner will build an ever enlarging background of meanings for these generalizations as he meets and solves his problems on higher and higher levels.

Applying principles in new situations. As it is important that the cycle of reflective thinking should start with problems that are inherently interesting and worthwhile to the learner, so is it essential that the cycle close with the application of principles to new situations which are close to his life experience. This should enable him to bridge the gap between the artificial classroom situation and the real life situation. It should also enhance the probability of transfer for the several abilities of problem solving which have been sought as desirable outcomes.

In attempting to provide classroom experiences which may lead to more effective application of principles, the following specific abilities may be used:

(1) Ability to recognize the common and identical elements in the principle and a new life situation.
(2) Ability to analyze or interpret new situations in the light of conclusions reached.
(3) Ability to synthesize elements in a new situation toward the formation of new and unique problems.

It is equally as difficult to separate the learning or development of the ability to apply principles from its evaluation, as was the case in the ability to interpret data. Each testing situation becomes a learning situation in so far as it reveals the weaknesses of the student with respect to that ability.

A teacher who has set this ability up as a desirable outcome no doubt would describe its attainment in terms of student behavior. For example, a teacher of biology might reasonably expect his students to apply the principles of biology in predicting or explaining natural phenomena or situations which have not been discussed in the classroom. Thus the attainment of the objective might be revealed by confronting the student with unique situations and asking that predictions be made and reasons given to substantiate the predictions.

The process of building up a set of principles in any given area of science through problem-solving techniques is an inductive process, while the application of the principle to new situations is largely deductive in nature. Principles are generalizations built up inductively from accumulated evidence, always enlarging and taking on new meanings in the light of new evidence. Principles may be used in predicting what will happen under a given set of circumstances or in the explanation of some phenomenon or event which has taken place. In either case, the method applied is deductive rather than inductive.

From the standpoint of learning, principles are very valuable. Since they are the result of cumulative and generalized experience, they make up the bases for classification of conclusions reached through problem solving. They are also economical in learning since it is much easier to remember a given fact or truth as it is related to some broad generalization than to remember it as an isolated element.

The Evaluation Staff of the Commission on the Relation of School and College of the Progressive Education Association[22] has developed some very valuable techniques and materials for evaluating the ability to apply principles which will be referred to and discussed at some length in Chapter 9 bearing on Evaluation. However, in developing these materials particularly for evaluation they have made some very significant contributions to the problem of learning the ability to apply principles. This is, of course, quite obvious when one considers the use of such tests as they have developed in relation to their diagnostic value. When a pupil has a weakness in any aspect of problem solving revealed to him through a test, there develops at once one of the most significant learning situations possible. For the student is anxious to correct his error, and the teacher is in a position to prescribe remedial instruction that meets the needs of the student.

Aside from this very important contribution to learning, however, the Evaluation Staff has made studies of the responses of young people to test items based on applying principles. These findings have been summarized in one of its bulletins dealing with the Application of Principles.[23]

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[22] *Ibid.*

It has found that the inability to apply principles may be due to one or more of the following causes:

(1) Lack of knowledge of principle involved.
(2) Failure to see that the principle applies in a given situation.
(3) Inability to tell why a given thing happened, even though the pupils can explain what happened or predict what will happen.

Further analysis of the written papers of these students revealed to the Evaluation Staff that in applying principles they may give false reasons; give irrelevant reasons for predictions; make unwarranted assumptions; use poor analogies; give poor authority; or make use of misconceptions of truth. From the standpoint of method, these findings are exceedingly important, for they point the way to the specific things in learning that teachers must be cognizant of it the pitfalls in applying principles are to be avoided.

The lack of knowledge of a principle involved means probably a low degree of mastery of the facts which have gone into the establishment of the principle. The failure to see that a certain principle applies in a given situation would seem to indicate that the student had made too few associations of the principle with real life situations.

There has been a point of view current in science teaching that if the laws and facts of a given science were thoroughly mastered, other abilities such as those involved in problem-solving behavior would develop. This is a false and unwarranted assumption which must be guarded against. If it is desirable that the outcomes of a science course, include such abilities, they must be taught directly. This does not mean that there will be any less emphasis on content, but that content mastery will cease to be an end in itself and become the vehicle by which significant problems are solved and other desirable outcomes attained. There is some evidence to show that content mastered in the solution of worth while problems has greater permanence than content mastered for its own sake.

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[23] Progressive Education Association, Evaluation in the Eight-Year Study, *Bulletin No. 5* (P.E.A. 898), "Application of Principles," December, 1936.

If science teaching is to serve its greatest possible function it must train young people to think. Thinking must be done with laws, facts, and principles. There is no quarrel with content as such on the part of those interested in problem-solving outcomes, but only with the use to which content is put.

QUESTIONS AND EXERCISES

1. Discuss the advantages and disadvantages of the lecture method as a technique of instruction in science.
2. Some teachers believe that questions asked of pupils are better begun with "How" or "Why" than with "What." Express your opinion on this contention.
3. Make the outline for an inspirational talk on a historical or biographical incident in science that might be presented to a high-school science class.
4. Plan the steps in a silent demonstration that might be used in a high-school science class. List the outcomes sought.
5. Criticise the instructional technique used in some laboratory science course you have taken in high school or college. Show how the technique used might have been improved.
6. Select some laboratory experiment from a high-school science course and criticize it from the standpoint of it being a true experiment. Rewrite the exercise so that it would conform to good experimental technique.
7. Formulate a set of criteria which might be applied to experiments in high-school science to judge their adequacy.
8. Write out the directions for a controlled experiment for some area of high-school science.
9. Criticize the list of things that laboratory instruction should accomplish, found on page 118 of this chapter.
10. Select some unit from one of the high school sciences and make a set of detailed plans for presenting it to a class by the unit-problem technique.
11. Suggest remedial procedures that might be applied to correct the various types of pupil errors given on page 128.
12. Make out a detailed lesson for developing one of the scientific attitudes with a high school science class.
13. Discuss the list of appreciations found on page 91 and add others to it.

14. Devise other techniques than those listed in this Chapter for developing scientific interest.
15. Construct a lesson plan in which you would attempt to develop the ability of a class to analyze a problem.
16. Select some experiment from one of the areas of high-school science, and write out a plan for using the data obtained to develop the ability to interpret evidence.
17. Make out a lesson plan where the major objective is teaching the skills of formulating and testing hypotheses.
18. Make out a lesson plan where the major outcome sought is practice in the skills of applying a principle to a new situation.

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Chapter 8

COLLECTING EVIDENCE IN THE LEARNING OF SCIENCE

Many of the day-to-day learning activities in science, such as reading, experimenting, watching demonstrations, field trips, and the like, are concerned with collecting information. It will be the purpose of this chapter to bring together and discuss various methods and practices that have been used to make this aspect of learning effective.

Learning what evidence is. Living in a modern world where emotional thinking and appeal are rampant makes it imperative that young people learn what the earmarks of good evidence really are. It is feasible to show them how evidence is regarded by the scientist; such procedures will, if properly learned, provide a safeguard against much of the questionable advertising and other practices so prevalent today. The following quotation is taken from an article by Henshaw Ward:[1]

> (1) Science cares only for indisputable evidence
> (2) If the evidence is conflicting, science balances the probabilities without running headlong to a conclusion
> (3) Unless the evidence so cumulates that almost all competent observers are forced to agree, science suspends judgment. How small a proportion of the population now has any conception of suspending judgment! How salutary it is for any one of us to learn to suspend!
> (4) Whenever new evidence appears, the true scientist welcomes it; he is as ready to have his previous theory demolished as to have it corroborated. He is guided by a curiosity that cares only for what the new evidence indicates.

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[1] Ward, Henshaw, "The Goals of High School Science," *Harvard Teachers Record,* October, 1933.

(5) Science recognizes that no amount of evidence is ever absolutely certain, that no knowledge is everlasting and immutable.

The consideration of "what evidence have you" to support an opinion is closely associated with the judging of relevancy of data, verification of an hypothesis, and other aspects of problem solving. In his excellent article Mr. Ward states further:

> The teacher who can give his class even an inkling of what true evidence is has made their intellectual lives safer and better.
>
> If he tries to expound the abstract principle, he will accomplish nothing. He can convey understanding only by putting before the class one concrete illustration after another, and so gradually bringing out the difference between empty "thinking" and real proof. The humbler the demonstration the better.

Skills essential to the collection of evidence. Evidence bearing on some topic or problem in science may be collected in a variety of ways. Each of these ways of collecting evidence is involved with a group of skills. If these skills are to be learned by pupils, teachers must provide opportunities for them to be practiced. The following listing has proven useful but should not be regarded as the only or the best way of classifying them. Nor should it be regarded as necessarily complete.[2]

1. Locating source materials.
    (a) Using various parts of a book
        (1) Using key words in a problem for locating material in an index
        (2) Using cross references
        (3) Using a table of contents
        (4) Using a glossary
        (5) Using figures, pictures, and diagrams
        (6) Using footnotes
        (7) Using topical headings and running headings
    (b) Using materials other than textbooks
        (1) Using encyclopedias
        (2) Using handbooks
        (3) Using dictionaries
        (4) Using magazines, pamphlets, and newspapers
        (5) Using various government publications
        (6) Using bibliographies

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[2] This analysis is based on outlines originally prepared by committees of the faculties of Colorado College of Education, Greeley, Colo., and the John Burroughs School, Clayton, Mo.

2. Using source materials.
    - (a) Using aids in comprehending materials read
        - (1) Finding main ideas in a paragraph
        - (2) Using reading signals such as italics and bold faced type
        - (3) Translating into one's own words statements from reading
        - (4) Phrasing topics from reading
        - (5) Skimming for main ideas
        - (6) Learning meanings of words and phrases from context
        - (7) Determining the main topics over several paragraphs
        - (8) Taking notes and outlining
    - (b) Interpreting graphic materials
        - (1) Obtaining evidence from various types of graphic material
        - (2) Noting relationships shown between factors
        - (3) Evaluating conclusions based upon data recorded
3. Solving mathematical problems necessary in obtaining pertinent data.
    - (a) Picking out elements in a mathematical problem that can be used in its solution
    - (b) Seeing relationships between these elements
    - (c) Using essential formulas
    - (d) Performing fundamental operations, such as addition, subtraction, multiplication, and division
    - (e) Using the metric and English systems of measurement
    - (f) Understanding the mathematical terms used in these problems, such as square root, proportion, area, volume, etc.
4. Using talks and interviews as sources of information.
    - (a) Selecting individuals who can contribute information to the solution of a problem
    - (b) Making suitable plans for a talk or interview
    - (c) Making arrangements with the person for the interview
    - (d) Selecting the main ideas from the interview
5. Making observations suitable for solving a problem.
    - (a) Devising a suitable demonstration
        - (1) Selecting materials and equipment needed in the demonstration
    - (b) Observing demonstrations
        - (1) Identifying and selecting important ideas demonstrated
    - (c) Selecting the important ideas presented by charts, models, exhibits, pictures, slides, motion pictures, radio and television
    - (d) Using the resources of the community for purposes of obtaining data pertinent to the problem
        - (1) Locating conditions or situations in the community to observe
        - (2) Selecting the essential ideas from such observations

Individual laboratory work versus demonstration lessons in collecting evidence on science problems. A considerable number of experiments have been reported of attempts to determine the relative merits of individual laboratory work and demonstration methods of teaching science. It is not feasible to give a detailed report of all these investigations here. However, it does seem desirable that science teachers become familiar with the conclusions arrived at by the investigators.

Stuit and Englehart[3] have made an excellent critical analysis of the lecture-demonstration versus the individual laboratory method of teaching high-school chemistry. The following is their summary of conclusions:

> In comparing the experimental evaluations of the methods of teaching high school chemistry, one is impressed by the variability of conclusions reported by the various investigators and the general inadequacy of the experimental techniques. It is evident that all the valuable outcomes of any one method are not tested by all the investigators.
>
> Much of the data seems unreliable and invalid due to lack of validity, and reliability of tests, doubtful control of teaching conditions, and the use of small, unrepresentative groups. Few writers base their conclusions on more than one trial. This hardly seems justifiable, for in any science, results require re-examination before they can be assumed to be dependable. In hardly any case is the method used by any one instructor exactly like that used by another. There is no standard demonstration or laboratory method. However, in order to arrive at a few general conclusions, it seems advisable to draw up a summary of the conclusions made by the investigators; of these the following are some of the more outstanding:
>
> Conclusions Contending That the Laboratory Method Is Superior.
>
> (1) "There is a slight indication that material was better retained when taught by the individual laboratory method." (Anibal)
>
> (2) "The order of preference of the methods studied places the individual laboratory method before the demonstration method." (Horton)
>
> (3) "In every respect the lecture method is least effective in imparting knowledge to high school students." (Wiley)
>
> (4) "For permanent learning the laboratory method is perhaps slightly superior." (Wiley)

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[3] Stuit, Dewey B., and Englehart, Max A., "Critical Summary of the Research on the Lecture-Demonstration versus the Individual Laboratory Method of Teaching High School Chemistry," *Science Education,* XVI: 380–391, 1932.

(5) "For providing knowledge and method of attack, the laboratory method is superior for the inferior pupil." (Knox)

Conclusions Claiming That the Demonstration Method Is Superior.

(1) "Bright pupils are more likely to profit by the lecture-demonstration method than are the others." (Anibal)
(2) "Dull pupils profit more from demonstration than from individual laboratory work." (Carpenter)
(3) "The lecture demonstration takes less time and costs less." (Anibal)
(4) "The teacher (demonstration) method is best." (Nash and Phillips)
(5) "Lecture-demonstration method gives better control over the individual since all are under teacher guidance." (Pugh)
(6) "For purposes of providing knowledge for both immediate and permanent retention and for the purposes of providing technique of handling new problems, the demonstration method is much to be preferred to the laboratory method in the case of average and superior pupils." (Knox)

Conclusions Contending That the Students Achieved Equally Well by Either Method.

(1) "Immediate retention is about equal in both demonstration and individual laboratory methods." (Anibal)
(2) "There is not as great a difference as is ordinarily supposed in the value of the three methods: lecture, textbook, and laboratory, so far as imparting knowledge is concerned." (Wiley)
(3) "The results of this experiment point to the conclusion that the majority of the students in high-school laboratory chemistry classes, taught by the demonstration methods, succeed as well as when they perform the experiment individually, if success is measured by instruments which measure the same abilities as are measured by these tests, namely specific information and ability to think in terms of chemistry." (Carpenter)

General Conclusions Based on Evaluation of the Reported Research. After considering the above conclusions the writers have arrived at a few ideas which seem justifiable in the light of the evidence given by this study.

(1) No method can be considered to be the best in every case. The objectives of teaching, the nature of the pupils, and the facilities of the school, will largely determine which method should be used.
(2) In small schools where money and space are not plentiful, the lecture-demonstration method seems to be the more practicable.
(3) The written test cannot be used to test all the outcomes of a course in high-school science. Some sort of manipulative tests seems necessary to test the laboratory skills.
(4) The problem of the relative merits of the lecture-demonstration and individual-laboratory methods still seems involved and as complex

> as ever. More careful experimentation, involving careful control of non-experimental factors and reliable testing, is needed in order to justify any definite and final conclusions. When experimentation has shown the relative superiorities of the methods in terms of outcomes the methods should be evaluated in terms of the value attached to these outcomes.

The conclusions arrived at by the investigators vary greatly and are indecisive. As a result, a controversy has arisen among science educators. Some hold that these investigations warrant the complete abandonment of the individual laboratory work in secondary-school science with the substitution of the demonstration method in its stead. Others claim that little or nothing has been proved by these investigations. It is likely, however, that science teachers will continue to find both laboratory work and demonstrations necessary for good science teaching.

The demonstration method does save time and expense. A saving of time from fifteen to fifty per cent has been reported by investigators. Anibal reports that the cost for a class of thirty taught by the demonstration method is only seven per cent as much as for a class where pupils work in two's at a table.

From the standpoint of economy it would seem that individual laboratory work should be assigned to a pupil when it is necessary for him to obtain information essential to the solution of his problem and which cannot be obtained first hand by other means, or when it is desired that he acquire certain manipulative skills.

In any event, when individual laboratory work is assigned it should be conceived as a means to an end and not an end in itself. Much of the laboratory work done in our present system is open to serious criticism, because in many cases it consists of little more than a pupil going through a set of motions following directions of a "cook-book recipe" type. It also frequently happens that pupils are asked to do laboratory work at certain hours, regardless of whether or not a need for it has arisen.

The point of view expressed here has been corroborated in an article by Cunningham[4] where the research on this controversial issue has been carefully reviewed and further by the Forty-Sixth Committee of the National Society for the Study of Education.[5]

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[4] Cunningham, Harry A., "Lecture Demonstration versus Individual Laboratory Method In Science Teaching, A Summary," *Science Education* XXX (March, 1946), pp. 70–82.

The effective use of the laboratory in collecting evidence. Much of modern educational practice is based upon the assumption that children "learn by doing." If this assumption be correct then there is no substitute for the laboratory when it is used effectively. Children passively watching a demonstration do not participate in learning to the degree that is possible when they are motivated by a real laboratory problem. Experimenting is naturally interesting and appealing to young people if its keenness is not dulled by going through a laborious set of directions to verify some principle they have already learned from the textbook.

Good laboratory work must be motivated by the spirit of discovery. It must leave room for pupils to plan procedures, make mistakes, and try various methods until they come out with evidence that can lead to conclusions and the satisfaction of having discovered something new to them. Laboratory work, especially in elementary and general science, can be improved by applying a few general principles. These are not new but they have been very well summarized by Blough:[6]

(1) Experiments should be conducted in such a way as to make pupils think.
(2) Children should be conscious of the purpose for performing an experiment.
(3) Careful planning is essential to successful experimenting.
(4) In so far as possible, children themselves should perform the experiments, working as individuals or as groups.
(5) Many times, children can suggest experiments to answer their own questions.
(6) Experiments should be performed carefully and exactly.
(7) Pupils should learn the value of controlled experimentation.
(8) Simple apparatus is more appropriate for use in experiments in the elementary school (and junior high school) than complicated material.
(9) Pupils should exercise great caution in drawing conclusions from experiments.

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[5] *Op. cit.,* p. 53.

[6] Blough, Glenn, *Specialist in Elementary Science,* U. S. Office of Education, Washington, D. C.

(10) As many applications to everyday life situations and problems as possible should be made from an experiment.

In collecting evidence on the solution of a problem, the student should be taught to collect as large a body of information as possible. He should make use of many sources, such as books, diagrams, pictures, and any other visual aids, such as motion pictures and stereoscopic materials. In this connection the teacher should also see to it that the student makes use of all local sources, such as the school environment, the home, and the community.

Experiments offer a peculiar opportunity in science for collecting exact information. The science teacher should see to it that every experiment contributes to the solution of a problem. In the past much of our so-called laboratory work has been largely "busy work" and has had little or no value in the solution of real problems.

Full value from experimental work is frequently lost because pupils have not learned to observe carefully and accurately. They get only general impressions from an experiment and rarely note exceptions or differences produced by the experiment. At an early time in the science experience of children much emphasis should be placed on training in careful observation.

The teacher should plan exercises both in and out of the laboratory which will call for the use of the skills of observation. It is often possible to locate the poor observers by performing one or more demonstrations before the class and and then having the pupils respond to questions either on a mimeographed sheet or placed on the blackboard.

Once the poor observer is located, special help may be given to him. He may be encouraged to train himself in the needed skills by such a simple device as looking in a store window containing many articles and seeing how many things he can name after a certain period of observation. There are also games on the market consisting of rather detailed pictures. After a certain observation period the contestant is asked to answer specific questions about the picture. Use of the same idea may be made in the laboratory by placing a variety of materials on the demonstration table and then providing a period of observation. The materials are then covered or removed and the pupils asked to answer prepared questions about the materials.

Some teachers have prepared observation charts for training poor observers. Advertisements are cut from a variety of magazines and pasted on cardboard to make a medley picture. These are then used as described above.

It is also possible to help the poor observer by making him responsible during a demonstration or experiment for observing and recording the evidence obtained. This creates a real need on his part and will serve to give practice in focusing his attention. It is also helpful to appoint several special observers and to compare their recordings in a short discussion following the demonstration. Whatever the method used, the teacher should be aware that skill in observation comes only with repeated practice.

Teachers often miss opportunities for developing the resourcefulness of pupils in laboratory work. At frequent intervals experiments should be planned with the pupils without reference to textbooks or laboratory manuals. It is good practice, also, at times when hypotheses have been proposed for the solution of a problem, to assign pupils the job of planning controlled experiments to test the hypotheses. Often most surprising and ingenious procedures will be suggested.

Perhaps one of the most neglected aspects of laboratory work is the failure of teachers to make the pupils aware of the fact that in every experimental exercise there are certain basic assumptions that must be made before the conclusion may be accepted as true. An assumption has been defined as any fact, theory, or principle of science, or element of procedure, which is a necessary part of the experimental exercise and therefore must be taken for granted and used to supplement the data before any conclusion could be accepted. For example, in an experiment to demonstrate that a black surface absorbs radiant heat energy to a greater extent than does a white surface:

Procedure: Using a white paper and glue, cover the surface of a small test tube. Similiarly cover the surface of another test tube the same size with black paper. Put equal amounts of water in each test tube and insert a thermometer in each, noting the temperature. Next hold each tube equidistant from a source of heat such as a large flame or an infra-red drying lamp. Note the temperature rise in each test tube during a given time interval.

Conclusion: Black surfaces absorb more heat energy than light surfaces.

Assumptions necessary to the acceptance of the conclusion:

(1) The heat conductivity of the two papers is the same.
(2) Both test tubes are receiving the same amount of radiation.
(3) Radiation from the two test tubes is approximately equal.
(4) Evaporation from the two tubes is not a significant factor.
(5) Both thermometers are accurate.
(6) That it is the color of the paper, and not some unknown factor which is significant.
(7) That the glue used has no effect on the experiment.
(8) That the student has well defined concepts of heat, conductivity, radiation, and temperature.

This rather commonplace experiment is used in many courses in general science and physics and yet not many teachers ever take time to make pupils aware of the assumptions basic to the acceptance of the conclusion. A little analysis of practically any experimental exercise in any area of science will reveal a wealth of assumptions for training in this important aspect of problem solving.

Controlled experimentation in collecting evidence. One of the claims advanced for science is that it has within it the potentialities for teaching logical reasoning and for cultivating proper habits of thought. The science laboratory would seem to be a natural place for pupils to engage in problem-solving activities. Unfortunately, too frequently the workbooks prepared for science classes are of such a nature that the pupil has little or no opportunity to engage in reflective thinking. Nor is the pupil given much instruction in methods employed to safeguard thinking.

The control of intellectual processes and skill in their use may be acquired through practice. Basically, the scientific method is a problem-solving method, and therefore if it is a worthy outcome of science instruction pupils should acquire facility with it along with a mastery of the laws, principles, and facts of science. Pupils need to be given practice in discovering problems, setting hypotheses, and in devising controlled experiments as a basis for verifying or rejecting proposed hypotheses.

(a) *Hypotheses.* An hypothesis is a tentative supposition through which we endeavor to solve a problem. It is a cautious attempt to discover order in any group of facts. Pupils should learn that the methods of science depend on fruitful hypotheses and that no hypothesis deserves serious attention unless it can be put to the test of observation either directly or indirectly.

(b) *Controlled experiments.* The experiment is the heart of the scientific method. There is an urgent need for science teachers to carry on laboratory work in such a way that pupils will learn the meaning and use of "controls" in experimentation.

Science teachers should encourage their pupils to study and analyze the work of famous scientists: how Robert Koch solved the problem of the cause of the disease anthrax, how Galileo discovered the law of falling bodies, how Gregor Mendel discovered the first laws of heredity, or how Pasteur discovered preventive vaccination for anthrax. These are thrilling stories through a study of which the pupil may gain a clearer meaning of controlled experimentation and a better understanding of the attitudes and thinking which characterize the work of the scientist.

In order that we may further clarify the importance of the use of "controls" in experimentation, let us examine several typical illustrations.

(1) *Do plants give off carbon dioxide?* This is a problem which may arise in a science class. A typical procedure in this experiment is as follows:

A little water is placed in the bottom of a wide-mouthed bottle. Some green leaves with their stems are cut from a healthy plant. The leaves are put in the jar with their stems in the water. Some lime water in a small dish is placed in the jar and the mouth of the jar is covered. After a while the limewater becomes white and milky. The pupil may report that this shows that leaves of plants give off carbon dioxide. But can he be sure this is true? Where is the control? It may be that the limewater turned milky from the presence of carbon dioxide in the air. The pupil must be made to see the necessity of setting up a control to insure the reliability of conclusions drawn. He could set up another jar with all conditions the same except that he would not put any leaves in it. Or he might apply a thin coating of vaseline to the upper and lower surfaces of the leaves and repeat the experiment.

(2) Another common experiment is the one on plant transpiration which uses the problem *"Do leaves of plants give off water?"*

The pupil is instructed to support a leaf of a plant by a piece of stiff cardboard with the stem extending into a glass of water. He then covers the leaf with another glass and places it in the sunlight. As mist gathers on the inside of the upper glass the pupil reports that this shows that leaves of plants give off water. Should the teacher leave this conclusion unchallenged? A number of questions arise. It may be that if this apparatus were set up without the leaf, under exactly the same conditions, the mist would form anyway. Even if his conclusion were true for this leaf, was it a typical leaf? Would leaves from other plants give the same results? Perhaps the teacher should require the pupil to repeat the experiment using leaves from a large number of species of plants. When Pasteur tested the efficacy of preventive vaccination against anthrax, he first vaccinated twenty-five sheep and when they recovered he vaccinated them again and used as a control group twenty-five sheep which had not been vaccinated before. The twenty-five sheep which had preparatory vaccination lived whereas the other twenty-five all died. His results were all the more convincing because he made his test between two groups of individuals rather than between two individuals.

The pupils should understand clearly the necessity of permitting *only one variable in an experiment.* The science of genetics was begun by Gregor Mendel, not because Mendel was such an intellectual giant that he could analyze the complex results which had baffled his contemporaries in breeding experiments, but because he had the brilliant idea of simplifying his experiments to the point where he was dealing with only one variable at a time.

Students should be taught the skills essential to good experimenting, but especially the importance of controlled experimentation. The average high-school student is able to understand and appreciate the need for controlling all factors in an experiment except the experimental variable. Experience has demonstrated that by wise questioning and suggestion the teacher can get students to state the purpose of an experiment, to suggest the experimental factor, and to plan necessary controls to make the results conclusive. Using such a cooperative scheme of planning experiments with the class will take much of the "cook book" out of laboratory work and revitalize it so that it becomes an interesting and valuable method of collecting firsthand information about a problem. This matter of controlled experimentation is so vital in the whole process of problem solving that another example will be given.

An eighth-grade class in general science had been studying oxidation and had noted that heat was given out in many instances. One girl said that the rusting of iron must be exceptional because no heat was given out when it oxidized or rusted. Her classmates challenged her to prove this and in the resulting discussion someone proposed that an experiment be performed to find out. How could such an experiment be performed? It was finally agreed that if any heat were given out it would be a very small amount and therefore some way would have to be devised to hold it in. The idea of the thermos bottle was proposed. The class had already performed the experiment of iron filings rusting in a test tube over water, so it was suggested that they could let iron filings rust in a stoppered thermos bottle with a thermometer to show temperature changes. The class was canvassed for thermos bottles and next day excitement ran high as they brought the thermos bottles to class. It was decided to use two experimental bottles and one control bottle. In each of the bottles the students decided to place a measured quantity of water at a given temperature. After rinsing the three bottles with the water, the control bottle was stoppered with a one-hole stopper carrying a thermometer. A weighed portion of iron filings was next placed in each of the experimental bottles, after which they were closed with stoppers carrying thermometers. Temperature readings were taken by class committees during the day at fifteen minute intervals and placed on the blackboard. On the next day the data were examined.

The boys and girls were greatly surprised to note that there had been very little temperature change in the control bottle, but that there had been a sudden rise in each of the experimental bottles followed by a slower rise and then a gradual drop to room temperature.

They were asked to draw inferences on the basis of the evidence and then to further test the inference by repeating the experiment with other materials made of iron such as tacks and small nails. After these tests had been performed, the students were ready to conclude that even in the case of the rusting of iron, heat energy was given out.

Lecture table demonstrations in collecting evidence. Teaching by the demonstration method is an integral part of science instruction. Science can never be adequately learned entirely from books. Beginners in science should be shown the materials and processes that are being talked about, and eventually they should handle the things themselves.

The science teacher who wishes to become a good demonstrator should know how to handle materials. He should also acquire skill in such things as glass working, soldering, cementing, working with tools, repairing instruments, and other operations with laboratory materials.

RULES FOR DEMONSTRATING

There are certain fundamental rules to follow in demonstrating. First and foremost, the *experiment should work.* Everytime the teacher has to say "Well, this is what should have happened" the confidence of the pupils is lessened. If, as it sometimes happens with the best demonstrators, some unforseen difficulty arises during a demonstration it may easily be turned into a genuine class problem. "Why did the demonstration fail to work?" "What will have to be corrected?" "Who would be interested in making the changes and presenting the demonstration tomorrow?"

Experiments should be as nearly infallible as possible. The secret of success in demonstration work lies, in part, in adequate and careful preparation before class time. No matter how experienced a teacher may be, he should set up the experiments and rehearse them before his class appears.

The materials to be used in a demonstration should be arranged carefully on the demonstration desk before the class enters the room. It is too late to set up apparatus after class has begun. It is very disconcerting for the pupils to watch the teacher fumbling around in drawers or closets for a piece of equipment which should have been on the table before the lesson began. In most cases where demonstrations call for definite quantities of chemicals it pays to have the stipulated amounts weighed or measured out before class time.

The apparatus should be on a large scale. The size of the apparatus which is best depends upon the size of the class. Obviously the apparatus must be large enough to permit every student in the room to see it clearly. Experiments which do not permit performance on a scale large enough for every pupil in the room to see clearly should hardly be attempted as demonstration experiments.

Demonstration experiments should be simple and speedy. It is advisable in demonstration work to use simple set-ups. Long drawn-out experiments with complicated and cumbersome apparatus are out of place in demonstrations. Pupils want to see things happen, and interest in the experiment lags when they have to wait too long. Other things being equal, the teacher should see to it that demonstrations move on quickly to a conclusion. There are of course exceptions to this rule, such as in plant experiments where time is a factor in the results.

An element of the unexpected sometimes increases interest in a demonstration. It is doubtful, however, whether a demonstration should be shown simply because it is spectacular. Every demonstration should raise a problem, illustrate or help to make clear some fact or principle, or illustrate an application of science. There are a few spectacular experiments which should be utilized by science teachers, but their scientific importance is to be emphasized rather than their value as entertainment.

Apparatus used in a given demonstration should be stored away intact until it is to be used again. This practice through succeeding years results in much economy of time for the busy science teacher. If this plan causes too much "dead stock" a modification may be used in which such articles as jars, flasks, beakers, and ironware are kept in common use, but only special pieces of apparatus are retained in some designated place for future use.

Common errors in demonstrating. The following list of statements gives typical errors in demonstrations made by beginning teachers. The list was compiled by Selberg[7] from observations of thirty-six student teachers in general science over a period of three years.

(1) The apparatus was not ready for use.
(2) The teacher failed to show how the demonstration fitted into the problem of the unit.
(3) The teacher failed to direct the students' attention to the important facts of the experiment.
(4) The teacher failed to allow pupils time to record data.
(5) The teacher failed to use the blackboard to aid the pupils in visualizing or comprehending a process, a plan, or the set-up of the experiment whenever the demonstration demanded it.
(6) The teacher failed to make clear to the student the reason for employing a certain technique and a control for the experiment.
(7) The teacher used more of the simple recall type of question.
(8) The teacher used a vocabulary unknown to the majority of the students.
(9) The persistent and continuous talking by the teacher did not challenge or stimulate the pupils to talk or ask questions.
(10) The minor facts were given as much consideration as the major ones.
(11) The teacher failed to aid the pupils in applying a generalization when the pupils themselves were incapable of completing this final step in learning.
(12) The teacher formulated the results and generalization rather than requiring the pupils to do so.
(13) The students' interest for further study was overlooked or not stimulated.
(14) The teacher failed to emphasize the generalization.
(15) The teacher failed to encourage the pupils to suspend their judgment until adequate data upon the problem were obtained.
(16) Insufficient drill was given in the formation of the generalization or its application.

THE IMPORTANCE OF READING IN LEARNING SCIENCE

Reading is perhaps the method most widely used by young people in collecting evidence. Observations and deductions made by others have been recorded, and in many cases these materials become available for use in solving a problem only through the medium of books, newspapers, magazines, or pamphlets. As teachers, we often assume reading ability on the part of the pupils without taking any steps to really know the extent to which they read effectively. There is little doubt that a considerable portion of the difficulties of pupils with science materials originate in their inability to use reading materials and comprehend the meanings.

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[7] Selberg, Edith M., "A Plan for Developing a Better Technique in Giving Science Demonstrations." *Science Education*, XVI: 417–420, 1932.

Young people receive most of their reading instruction and probably most of their reading experiences through English and language classes. In these experiences the pupils are called upon to do certain types of reading and thus develop specific reading habits which may or may not be useful in reading in other areas. It is also true that these reading habits are further set by the kind of leisure reading done by the young people. Most of their leisure reading is, and perhaps should be done, for pleasure and not for retention or for securing exact meanings. Thus it is not surprising that when these students with a definite pattern of reading habits come to other areas, where a different type of reading is demanded, they experience some difficulty. It is also true that teachers in areas other than English have assumed that responsibility for the development of good reading habits was strictly a problem for the English department. It is essential that this point of view be broken down and that in any area, such as science, where a special type of reading is demanded, the teacher in that area assume responsibility for discovering the difficulties and improving the reading techniques of the pupils. This involves first knowing the important skills involved in the specialized reading; second, discovering the weaknesses of pupils in these skills; and third, planning procedures for improving the skills.

Difficulties in reading science materials. Reading specialists have built up in the minds of both pupil and teacher the belief that there is some great virtue in the ability to read with speed. Somehow these experts have failed to make clear that it is the rate of comprehension or understanding that really matters and not the mere speed of covering materials. In science, reading passages are frequently packed with words which are in themselves concepts made up of interrelated partial meanings. In reading such passages, it is essential that a pupil weigh and perhaps engage in interpretation, inference, or application. Certainly in such a situation mere speed is not a virtue.

It is of little value to a pupil if he reads rapidly and in so doing reads falsely. Where he is forced to read for exact meanings the penalty for not doing so may be severe. A reader who fails to grasp the precise meaning of questions asked in tests, the directions which are printed for an experiment, or the exercises set up in a workbook, may not only come out without the information needed, but may actually be led astray. All further activities initiated by and dependent upon the reading may be nullified.

In the area of science there is a considerable body of evidence which seems to reveal the almost impossible task that the technical vocabulary of the various subjects imposes on the pupils. If pupils were to do no more than master this vocabulary in the span of nine or ten months, they would make a fine achievement of a sort. When we realize that in many of our science textbooks there is used a technical vocabulary of several hundred words not found in the ten thousand most commonly used words of the English language, we are able to see, in part, a reason why young people have difficulty in comprehending reading materials in our field.

The solution of this problem is in part the responsibility of the textbook writers and in part a problem for the science teacher. Curtis[8] has made available a comprehensive study of the vocabulary problem in science. This study should prove helpful to teachers and textbook writers in the field, for it indicates the words that need clear definition in the various science subjects.

As writers of textbooks become more aware of the seriousness of the vocabulary problem in the learning of science, there will no doubt come some simplification of many of the technical terms used. It is also true that in a specialized area, where many words have come to represent concepts, it will not be possible for writers to oversimplify the vocabulary. It is here that the teacher must assume responsibility in helping the student, through other learning experiences, build up meaning and understanding of the difficult technical words.

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[8] Curtis, F. D., *Investigations of Vocabulary in Textbooks of Science for Secondary Schools.* Ginn and Co., Boston, 1938.

Placing a glossary in a textbook may be a partial solution for the problem of vocabulary. However, it is generally true that pupils do not make use of the glossary. Teachers should provide frequent opportunities, demanding the use of both glossary and dictionary, and insist on precise and accurate definition and use of technical terms. It is also important that textbook writers realize that words defined in the body of the text are more likely to become a permanent part of the pupils' vocabulary than those in the glossary.

Inefficiency and ineffectiveness in reading often result from the pupil's failure to know about and know how to use the various aids in a text or reference book. It is quite common to see a student, looking for a page reference to a key word, using the table of contents rather than the index. A teacher should be very certain to acquaint the student with the various parts of a text or reference and the proper use of each. He should point out devices, such as bold-faced type, italics, underlining, etc. used by the author for special purposes. It is also essential that pupils be given practice in the use of these devices, either during supervised study or through written exercises. Time thus spent will be repaid in more effective reading later in the course.

Developing good reading habits. In so far as effective reading of science materials is concerned, the main problem is not one of reading for enjoyment, but rather one of reading for intellectual comprehension. This is not to imply that science is void of the other types of reading materials, but rather to emphasize that for purposes of solving problems most reading is used for the collecting of evidence. Reading for intellectual comprehension in science is probably not greatly different from reading in other specialized areas except for the vocabulary and phraseology which is peculiar to science. The following list includes some of the major problems found in reading for comprehension:

(1) The recognition of symbols, and the association of meanings with symbols.
(2) The synthesis of small thought units into larger meaning units.
(3) The selection of pertinent elements bearing on a problem and the rejection of others.

(4) The organization of thoughts according to the purposes with which the reading was done.

If the science teacher is alert to such difficulties offered to young people by reading, he should be in a better position to build up effective reading habits. This, of course, assumes that the teacher will make frequent opportunities for the pupil to reveal his reading ability. It is also important that the pupil be made more aware of problems involved in reading science materials, and that he be encouraged to diagnose his own difficulties and attempt to correct them.

The following list of skills involved in effective reading have been included so that the teacher may be rather specific in discerning the difficulty of a pupil, and in proposing remedial work:

(1) Skill in reading with a definite purpose or problem in mind.
(2) Skill in determining the author's point of view and central theme.
(3) Skill in summarizing.
(4) Skill in associating what has been read with the reader's experience.
(5) Skill in evaluating a passage for the purpose for which it is being read.
(6) Skill in varying the rate of reading both with the purpose and the difficulty of the materials.
(7) Skill in reading despite distraction.

For nearly every one of these skills it is possible for the teacher to set practice conditions in the classroom. Such periods of practice need not be lengthy, but should be reasonably frequent, especially on the lower levels and at the beginning of a course while the teacher is attempting to locate the reading problem cases in the class. In the junior high school it has been found that a little time in the supervised study period devoted to individual reading aloud may reveal many weaknesses which might otherwise go unnoticed.

If effective reading is to be achieved, it is essential not only that practice in the general skills be provided for, but also that we, as teachers, be aware of the different types of reading that students may encounter. Such recognition makes it possible to give more helpful guides to lesson preparation and also to set definite exercises which will call for the use of the skills involved in the particular type of reading. Some of the types of reading that may be encountered by pupils are:

(1) Reading for comprehension
(2) Reading for fact-finding
(3) Reading for retention
(4) Reading for analysis and evaluation
(5) Reading for enjoyment

It is, of course, quite probable that many of the reading assignments in science will involve more than one of the above types. The pupil should be taught to discern these types and employ the specific skills accordingly.

In teaching pupils to read for comprehension, it is essential that they learn to select topic sentences, locate details, and summarize and outline paragraphs. These skills may be developed by having the learner answer questions about a passage, outline what has been read, or prepare a list of questions answered by the assignment.

It may also be helpful to ask pupils to reread a passage, consulting dictionaries and other references to get meaning from troublesome parts. Another suggestion is to have pupils read rapidly through several pages, checking all references to a given law, principle, or theory. Pupils need to have practice in the skill of translating the words of an author into his own words. This can be done by assigning a passage to be read silently and then having a pupil give the meaning in his own words. Encourage the other pupils to be constructively critical of the translation. Pupils need also to be taught the skill of rethinking what he has read. Some authorities say that when reading for exact meanings one should spend as much time in rethinking as he does in reading.

Reading for factual information implies reading for detail. Practice in this may be given by asking pupils to collect facts from an assignment to support a judgment about a person, a place, a theory, hypothesis, law, or principle. Another approach may be to ask pupils to find specific answers in the text to definite questions. They may also be asked to find facts that will refute a statement presented. It is also possible for the teacher to give the gist of a certain paragraph and set pupils the problem of finding the passage.

Honest and intelligent skimming is often a very great help in reading for factual information. There is a difference between skimming and rapid reading which few pupils recognize, yet is very important. Skimming means looking to see what is in a paragraph and deciding quickly whether you need the information or not. It is a rapid evaluation of the content. In teaching pupils the skills of skimming, the following devices may prove helpful:

(1) Ask them to read under the pressure of time and permit them to take notes to be used in discussion.
(2) Teach them to look for topical sentences and key words and phrases.
(3) Ask a question specifically answered in the assignment and see who can first find the passage which answers it.

When an assignment demands reading for retention, pupils may be asked to underline statements that are important and take notes on important facts or statements bearing on the problem being solved. It is also helpful to have them summarize an assigned passage and show how it relates to the problem.

Reading for analysis and evaluation calls into play the ability to discriminate between essential facts and irrelevant material. The pupil may be given the problem of comparing the viewpoints of two or more authors on a certain problem in science. Again, he may be asked to explain what the author means by certain words or phrases used in the discussion of a given science problem. Another device for developing ability in this type of reading is to give the point of view of some writer on a certain science problem, law, or theory, and ask the pupil whether the author of the book they have read on the same topic agrees or disagrees.

A few suggestions as to how teachers may help pupils avoid reading difficulties are suggested:

(1) Go slowly and make certain that pupils understand the work.
(2) See to it that periods devoted to the recognition of new words and symbols are frequent.
(3) Have an ample supply of dictionaries in the room and see to it that pupils are forced to use them.
(4) Devote time frequently to having the pupils read aloud from the assignment.

(5) Be sure that the assigned materials are within the range of the student as far as comprehension and vocabulary are concerned.
(6) Provide for use and repetition of new words and symbols.
(7) Select books with good illustrations and teach pupils the proper use of illustrations.
(8) Teach pupils to rethink passages read.
(9) Select books with adequate indexes, glossaries, and footnotes.
(10) Teach pupils to read thoughtfully and attentively, to question, doubt, approve, disagree, modify, and compare as they read.
(11) Teach pupils how to weed out irrelevant facts and ideas.
(12) Teach pupils to seek relationships in the passages they read, and to relate their reading to the problem at hand or to their general background of experience.

The relationship of wide reading to growth in science. A comprehensive study of the effects of wide reading in general science was made by Curtis.[9] The results of his study show that (1) when pupils are given the proper encouragement, and have access to suitable books and magazines, they will read a great amount of scientific literature for recreation along with their regular school work; (2) an effective way of providing for individual and sex differences is through the medium of extensive reading; (3) extensive reading of scientific literature stimulates the desire of some of the pupils to proceed further with the study of science in school.

In many instances science teachers do not take advantage of the values to be gained from wide reading in science. Books on science in the school library are used only incidentally in the preparation of reports and for general reference. In some schools science teachers work closely with the school librarian and with the English department in building up a group of science books for general reading. English teachers usually require pupils to do outside reading and are usually very willing to accept scientific literature as a part of their requirement.

The effective use of source materials. Books are among the most important sources of material used in solving science problems. In some places where library facilities are poor, this source may be confined to the textbook and perhaps general references such as an encyclopedia. In other cases the library is the heart of the school. In either case it is important that pupils learn good techniques for locating materials. Where there is a trained librarian, the science teacher may work in close cooperation and perhaps provide time from the science class for the librarian to give instruction and help. In places where there is no school librarian, it may be possible to call in the town librarian. It may be necessary in some instances for the science teacher to give the needed instruction.

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[9] Curtis, F. D., "Some Values Derived From Extensive Reading of General Science." Ph.D. Thesis. *Contributions to Education* No. 163, Teachers College, Columbia University, 1924.

The pupil should be made to realize early in his science experience that books are tools and they must be used skillfully if the best results are to be attained with them. It is important that instruction be given in the parts that make up a book. The table of contents is an outline of the book and is used for locating specific chapters, general areas, or subtopics. The boldface type used throughout a chapter is an outline of the chapter and has many important uses. Pupils should be taught the use of illustrations such as pictures, graphs, tables, and drawings. These are amplifiers of the text and often add precision and form to the mental image derived from reading the text.

It is important, in the solution of a problem, that pupils learn how to pick out key words in the problem that may lead to information bearing on its solution. For example, in the problem "How is a supply of pure water obtained?" the key words for use in obtaining information on the problem are *water* and *obtained.* Drill in selecting the key words in problems should be provided by science teachers. This selection of key words will call for instruction in the proper use of book indexes and the selection of proper subtopics within the index. It is not uncommon to find even in pupils of junior high-school age an inability to handle alphabetized materials with efficiency. Young people may go through an entire year with a textbook without discovering that there is a glossary or an appendix in the book or learning how these may be helpful to him in securing evidence. The use of the dictionary or glossary may be motivated by having pupils read parts of the assignment aloud. They are almost certain to stumble over pronunciations or to lack an understanding of certain terms. These, then, become real needs and the dictionary, glossary, or footnote may be pointed out as an aid for use. The use of these devices must be fixed as habits.

Other devices, such as cross-references, running headings, marginal headings, and bibliographies should be pointed out to the pupil and instruction should be given in their proper usage. For example, chapter or appendix bibliographies often furnish valuable leads for additional information on a problem under investigation.

In the use of a text or reference book, it is also important that marks of emphasis used by publishers be called to the pupils attention. These may be such devices as boldface type, italics, and underlining. If books are purchased or owned by the pupil, it may be well to encourage him to develop his own scheme of marking important ideas or passages by marginal notes, underlining, or some other device. Where books do not belong to the pupil, it may be wise to have him take notes from the reference bearing on the solution of his problem.

Securing information on a given problem may call for the use of other devices, such as handbooks, identification keys, magazines, newspapers, pamphlets, bulletins, catalogues, etc. The teacher should see that whenever such devices are called for, the students are given adequate instruction and practice in their use.

It is essential that students be instructed in the plan, arrangement, and proper use of library facilities. It is often true that young people waste much valuable time using a trial-and-error method in locating library materials. Early in his school experience the pupil should be taught the use of the card index, the *Readers' Guide,* general references, bound magazines, and other essential features of the library.

Reliable sources of information. The solution of problems both in school and out demands that the information upon which hypotheses and conclusions are based must be accurate. We are living in a period when through radio, television, the newspaper, and other agencies, we are likely to be flooded with spurious advertising and unreliable information.

There are many organizations and institutions which furnish dependable materials, either free or for a very small cost, bearing on problems in science. A suggestive listing of some of these agencies will be found in the Appendix. These agencies include departments and bureaus of the federal and state governments, scientific societies, and certain large corporations and industries which have high ideals of service. Museums, zoological gardens, botanical gardens, city aquariums, and city planetariums are sources of reliable information. In recent years several consumer organizations which maintain testing laboratories have been set up. These organizations supply confidential information on many consumer materials to subscribers.

The library is also a source of reliable information available to a large number of communities. In using books and pamphlets as sources of information, it is essential that one be careful in selecting. Not all that is printed is reliable. One should always look at the title page and check the author. What degrees does he have? Is he a recognized expert on the subject about which he is writing? It is also important to check the date of publication of the book. Science and technology are moving forward at such a rapid rate that a book published even five years ago on some scientific subject may be out of date today.

In attempting to get reliable information on a problem, the opportunities of the local community should be kept in mind. In almost every locality there are experts on certain science subjects. The local doctor, dentist, hospital, health officer, and water commissioner can supply information on aspects of health. Service station attendants, garage mechanics, etc., can give information on mechanics. A carpenter or builder can give information on house construction, and the plumber, the electrician and many others can also supply valuable help on certain problems. A community survey of resources made at the beginning of the year may be a very worthwhile project for the science class.

QUESTIONS AND EXERCISES

1. Discuss the claims made for the laboratory method of teaching science and the claims made for the demonstration method.
2. Write out a set of plans for conducting a laboratory experiment in some area of high-school science. List the outcomes sought, introductory

questions, statement of the problem, directions for collecting evidence, discussion questions on the results of the experiment, etc.

3. Show how the plan for Exercise 2 would have to be modified if the materials were to be presented by the demonstration method. Present the demonstration in class as you might give it before a high-school group.
4. Plan a class period in some area of high-school science in which you would set up a controlled experiment for the following day, through cooperative planning with the class, and where the class would devise their own laboratory directions.
5. Write out a series of suggestions that will give your ideas on how the laboratory period in high-school science can be made more effective as a means of collecting reliable evidence on problems.
6. Assume that you are teaching in a community where the school affords few library facilities. Select some problem that a science class might be working on and outline plans for utilizing the resources of the community for collecting evidence on the problem.
7. Outline some remedial procedures that you might use in developing skill in observation for pupils who were deficient in this respect.
8. Select five experimental exercises from some area of high-school science. Analyze the purpose and conclusions and list the basic assumptions that must be made if the conclusions are to be accepted. Indicate how you would provide for these assumptions if you were teaching these experimental exercises.
9. Select three experimental exercises from some area of high-school science which in their stated form are not controlled experiments. Rewrite these exercises in the form of controlled experiments.
10. Write a critical evaluation of the "Rules for Demonstrating" found on page 171, of this chapter.
11. Work out a set of practice exercises that you might use to develop skill in each of the following:
    (a) Use of the table of contents of a book.
    (b) Use of the index of a book.
    (c) Locating information on a specific problem in a general reference.
12. Outline steps that you as a teacher might take to improve reading skills in a group of pupils who were poor readers.

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Chapter 9

THE EVALUATION OF LEARNING IN SCIENCE

There is probably no aspect of instruction in the secondary-school curriculum today that is changing as rapidly as the evaluation of learning products. The changing philosophy of the secondary-school curriculum is shifting the emphasis of evaluation away from the exact measurement of mastery of content in a given area, as the only index of achievement, toward an attempt to evaluate other outcomes, such as aspects of thinking and desirable attitudes.

Guided by philosophies similar to the one set forth in Chapter 1, the function of instruction in the modern school is gradually shifting away from the content-centered curriculum toward a vitalized, life-problem-centered type of procedure. This does not imply that content is mastered to any less degree but rather suggests a shift from content mastered as an end in itself to content mastered as a means of solving problems.

It is quite obvious that the appraisal of the growth of an individual toward goals, which have been set on the basis of his life needs and interests, is a far more subtle and involved task than measuring the degree to which a student has mastered the facts of biology or chemistry.

Evaluation as such cannot be separated from other fundamental aspects of the curriculum, namely the educational goals and the instruction. Curriculum workers in the past have done a minute job of determining goals in an objective manner but often have left the evaluation of growth toward these goals to the specialists in the various subject-matter areas. The only type of evaluation program that can reveal the growth of a student toward certain goals is one in which the instruments of evaluation have been set up on the basis of the objectives or goals of the course.

An evaluation program which would attempt a complete appraisal of a student's growth in science or any other subject area has several obligations: first, to devise tests and measures that will reveal not only the mastery of facts and principles of a given area, but also a functional understanding of the concepts and generalizations involved; and second, to devise techniques for revealing growth in certain other outcomes such as the elements of reflective thinking, attitudes, creativeness, personal interest, and social sensitivity.

A further obligation of an adequate evaluation program, equally as important as the appraisal of achievement, is that of detecting, as early as possible, the strengths and weaknesses of students with respect to the objectives or goals of the course. Evaluation instruments must have the property of diagnosis if there is to be any effort made to have students proceed at a rate commensurate with their ability.

EVALUATION PROCEDURES WHICH MAY BE USED

It has become all to common to regard evaluation in science and in other areas largely in terms of paper and pencil tests. Written tests and examinations have been the mainstay of judging the achievement and the progress of pupils from the earliest days of education. Valuable as they have proven to be, written tests have very real limitations when evaluation is regarded in terms of the total growth of the pupil. For at best a pencil and paper test can reveal only how a pupil reacts to a situation that is described; there is no assured relationship between this type of behavior and the way he might react to a "real life" situation. Teachers are constantly seeking ways of supplementing the paper and pencil test to make their appraisals of the growth of pupils more reliable.

It is not the purpose here to appraise the merits of evaluation procedures nor to discuss their administration. Such discussions may be found in the standard textbooks devoted to the problems of evaluation. It is important that science teachers become familiar with the various kinds of devices that may be used for purposes of evaluation. The following list was adapted from Chapter 15 of the *Forty-Sixth Yearbook* of the National Society for the Study of Education. Samples of many of these devices will be given and discussed as they apply to certain evaluation situations.

1. Evaluation by paper-and-pencil devices:
    (a) Verbal tests, either "objective" or "essay" in form,
    (b) Diagrams, pictures, charts, etc.,
    (c) Rating scales and check lists.
2. Analysis of work products according to acceptable criteria (apparatus set-ups, notebooks, student collections, committee reports, etc.).
3. Classroom questioning and discussion.
4. Observation of significant behavior, either:
    (a) Informal, as in day-by-day classroom or laboratory activities, or,
    (b) Systematic, as in situations specifically planned to elicit known types of behavior.
5. Conferences and interviews with individuals or with small groups.

Evaluating Growth in Functional Understanding

Even though there has been a rapid development in the past few years in the direction of evaluating outcomes of science teaching other than mastery of content, this objective is still important and no doubt will continue to be. The fault in the past has been that content mastery was the only outcome indicated, and pupil growth in a subject area was determined on this single criterion.

When problems are solved by young people in science, it is essential that they come out with mastery of certain facts and principles or an enlarged understanding of a science generalization. This knowledge must be evaluated, for it is an important aspect of the total growth of the student in a given science area. Exact thinking demands mastered facts and principles, and this mastery may be evaluated by the application of techniques which have been developed through the many available subject-matter tests over the past twenty-five years.

While it is important, as a measure of growth in knowledge outcomes, to give end-of-semester or end-of-year mastery tests, it is generally thought that the principal function of such measures is for instructional purposes. Mastery should be tested during the year at frequent intervals to enable the teacher to judge the completeness of learning and to be in a better position to prescribe remedial work while there is still an opportunity to do something about it. When the evaluation of mastery is left to the end of the year there is little that can be done for the pupils who show weaknesses. A frequent testing program is a stimulus both to teacher and pupils.

At the present time there are many end-of-year and also unit tests on the market covering the several areas of science teaching. It is quite common now to find textbooks accompanied by unit-testing programs either included in workbooks or separately. This seems to be a move in the right direction. With the shift of emphasis away from logically-organized courses in the high-school science toward courses where content is organized around problems of pupil adjustment, there may be less demand for instructional tests based on units and chapters of textbooks and an increased demand for teachers who are using a certain problem organization to build their own mastery tests. Such a procedure, of course, will not alter the validity of techniques now used, but will mean simply a different organization of test items.

A study of available mastery tests in the sciences will reveal several acceptable testing techniques in use. Many of these techniques are adapted only to the evaluation of fact acquisition, although some may be used for testing the understanding of generalizations or even the application of principles. The techniques developed by Tyler for evaluating outcomes of reflective thinking seem to have considerable promise for application in the area of content mastery as well. At the present time there is great need for tests designed to evaluate the mastery of laboratory techniques and procedures.

A common mistake in the use of all evaluation instruments in high school science is to apply the tests only at the close of a unit of instruction and then to assume that the performance on the test reveals growth. This may or may not be the case. To reveal the results of instruction in a given learning period, it is essential that a pre-test be given before the instruction and a mastery test following the instruction. The difference in performance on these tests will be a more reliable index of student growth in the outcome being tested.

Paper and pencil devices have long been used as a means of evaluating functional understanding in science. A few sample items of various types that may be used in such tests are suggested below:[1]

Sample 1. Essay questions.

Demonstration: A little water is placed in the bottom of a can (e.g., a varnish can). A cork fits snugly into the opening of the can. The water is heated until it boils and steam escapes. The cork is then inserted tightly, and the source of heat is immediately removed. The can is allowed to cool. Then the sides will be seen to collapse.

Questions (to be answered by pupils):

1. Just what does this demonstration really show? What can you conclude from it?
2. List the important things which you actually observed or saw happen and those things which would need to be mentioned in explaining what happened.
3. Indicate some of the things which you assumed or took for granted, i.e., things which would be necessary in explaining what happened.
4. Show how the points which you actually observed and those which you assumed helped you to arrive at your conclusion (in 1).
5. Why was the source of heat taken away immediately after the cork was put in?
6. What was the purpose of boiling the water?
7. Indicate one or two other ways in which the purpose for which the water was boiled could have been accomplished.
8. Why doesn't the gasoline tank in the rear of an automobile collapse in a way similar to the can in this demonstration when a full tank of gas has been used up?

Sample 2. Essay questions.

Demonstration: A flask is filled with HCl vapor by displacement of air in the usual way. A single-hole stopper is arranged with a glass tube extending into the flask and with a rubber tube attached which extends a short distance outside the flask. The rubber tube should be provided with a pinch clamp (or it may be closed and opened by pinching with the fingers). As soon as the flask is filled with vapor, the stopper with tube is inserted, the flask is inverted, and the closed end of the rubber tube is placed under water in a beaker. When the end of the tube is opened, the water rises into the flask to make a fountain. If a little blue litmus solution is put in the lower beaker, the fountain becomes red.

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[1] These have been used by permission from the publishers of the *Forty-Sixth Yearbook* of the National Society for the Study of Education.

QUESTIONS (to be answered by pupils):

1. If the flask was full of HCl vapor, what caused the water to start to rise in the tube?
2. As the first few drops of water entered the flask, what happened?
3. Why didn't the fountain continue indefinitely as long as there was a supply of water in the beaker?
4. Where should the end of the glass tube be located: near the top of the inverted flask, toward the middle, or down into the neck, or doesn't it make any difference? Why is this?
5. Why should the blue-colored water become red in the fountain?
6. What property of HCl vapor is illustrated in the questions and answers to Nos. 1, 2, and 3?
7. Which of these illustrate physical and which chemical properties?
8. If a piece of dry red litmus paper had been placed in the flask of HCl vapor before the fountain was started, what change would you predict should have taken place? Why?
9. If the HCl vapor had been compressed into the flask, so that the flask contained, say, twice as much as in the demonstration described, and if the same procedure had been followed, what do you think would have happened? Indicate your prediction and reasons why you think this would have happened, then try it out. If, when you try it, the results are different, can you give the reason for what did happen?

Sample 3. Objective questions.

DEMONSTRATION: A storage battery is connected in series with a tap switch by means of flexible wire, with a suitable resistance to permit a flow of from five to ten amperes. The wire is arranged so that it can be placed first just above, then just below, a compass needle, extending parallel to the N-S direction of the compass. When the switch is closed with the wire above the compass, the needle turns at right angles to the wire; when closed with the wire below the needles, it turns at right angles in the opposite direction. When the switch is open, the needle returns to its normal N-S direction.

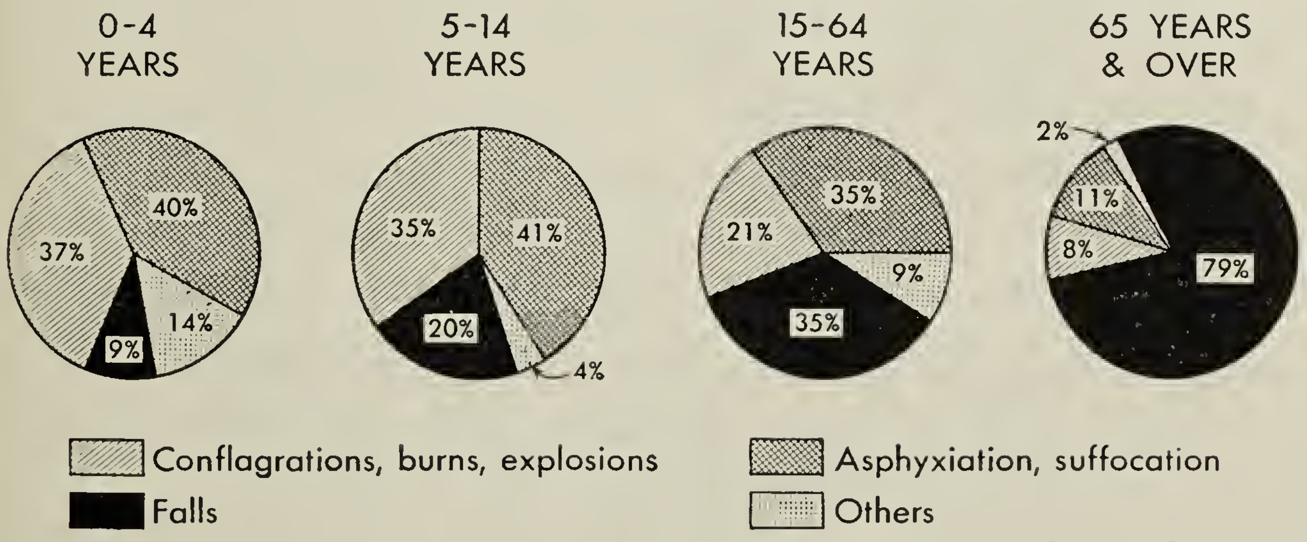
QUESTIONS (to be answered by pupils): A check or cross is to be placed before statements which are justified on the basis of the demonstration.

________ 1. Electricity is magnetism.
________ 2. A stronger current will produce greater magnetism.
________ 3. The wire carrying the current is magnetized.
________ 4. The same magnetic effect is produced anywhere along the wire.

________ 5. A current-carrying wire produces a magnetic effect.
________ 6. An electric current is magnetized.
________ 7. Reversing the poles would reverse the direction in which the needle would turn.
________ 8. In a current-carrying wire a magnetic field is produced which is in concentric circles around the wire.
________ 9. The current above the needle is opposite in direction to that below the needle.
________10. This demonstration (or experiment) is known as Oersted's experiment.
________11. Magnetism always acts at right angles to the electric current producing it.
________12. Magnetism can produce electricity.
________13. One end of the wire is an N-pole, and the other an S-pole.
________14. Magnets can only be made by electricity.
________15. The electricity was the cause of the magnetism.
________16. This illustrates the principle of the electric motor.
________17. Copper wire does not retain its magnetism, as does iron.
________18. Magnetism cannot be separated from an electric current i.e., it always is present if a current is flowing.
________19. The magnetic field around a current-carrying wire is similar in shape to that of an ordinary magnet.
________20. The magnetic force above the wire is in an opposite direction to that below the wire.

Sample 4. Essay question, with no leads.

List the conclusions that may reasonably be drawn from the data given in the graph below.

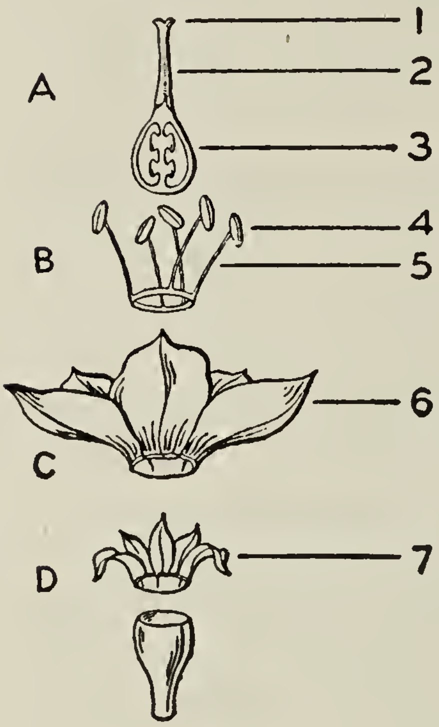


(Courtesy of National Safety Council)

Home Fatalities by Age and Type

Sample 5. Identification, completion type.

DIRECTIONS: In the cut at the left the parts of a dissected flower are shown. Identify each of the four main parts (A, B, C, D) by writing the correct name of the part after the proper letter below.



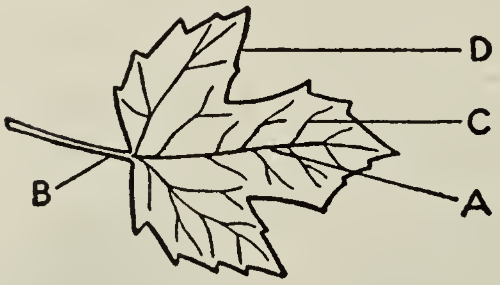
The lettered parts of the flower in the diagram are followed by a number or numbers to indicate sections which may be further identified by name. Write the name for each of these parts in the blank after the proper number.

1. ____________
A. . . . . 2. ____________
3. ____________
B. . . . . 4. ____________
5. ____________
C. . . . . 6. ____________
D. . . . . 7. ____________

The Parts of a Typical Flower

Sample 6. Identification, completion type.

DIRECTIONS: At the left is shown a diagram of a leaf. At the right is a list of words which name parts of the leaf. After each word write the letter for the part of the diagram which illustrates the meaning of that word.

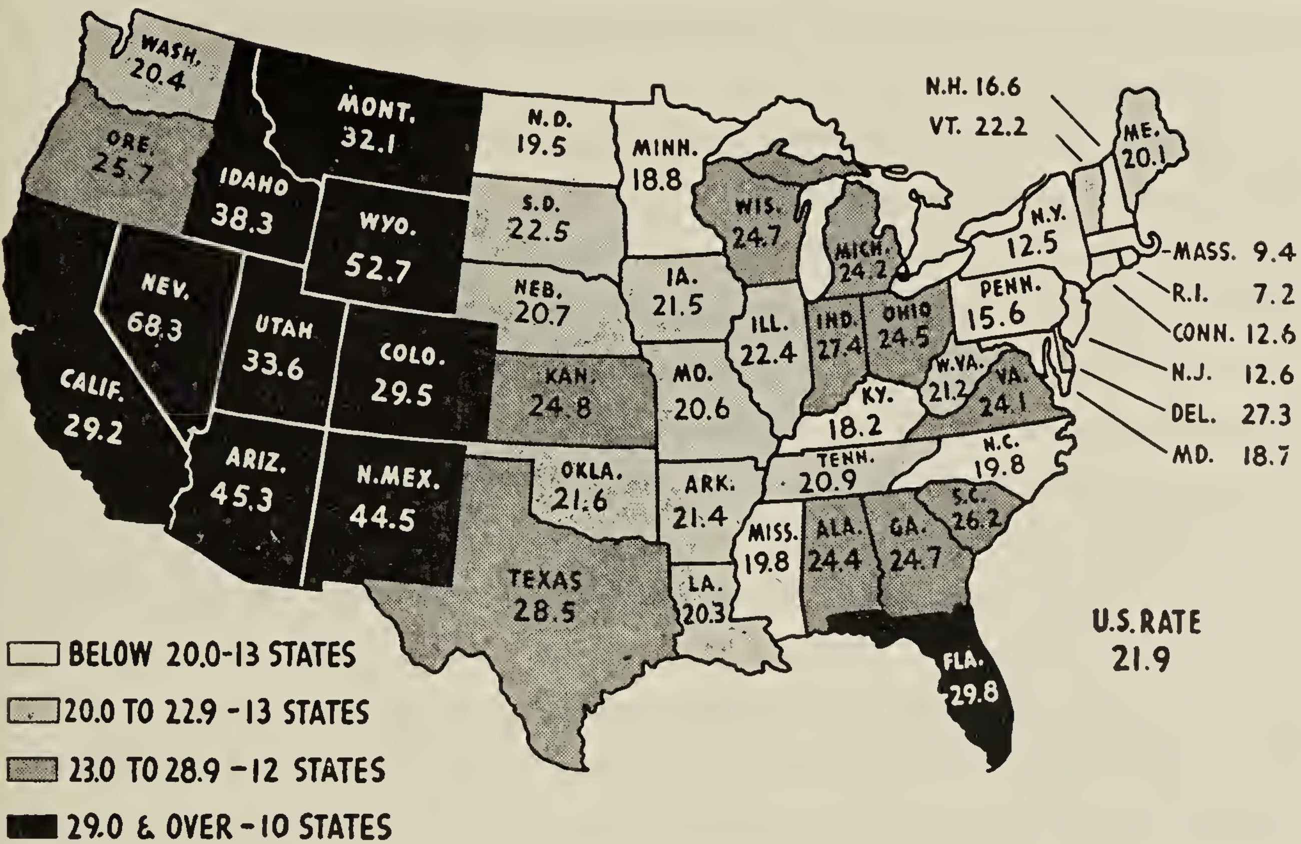


vein ____________________
mid-rib ____________________
stem ____________________
lobe ____________________

Sample 7. Objective questions, relatively simple in character.

From the following list of conclusions, check those that can be supported by the data in the map on page 195.

________1. The darker the shading of a state, the larger the relative number of motor-vehicle deaths.


WASH. 20.4
ORE. 25.7
CALIF. 29.2
NEV. 68.3
IDAHO 38.3
MONT. 32.1
WYO. 52.7
UTAH 33.6
COLO. 29.5
ARIZ. 45.3
N.MEX. 44.5
N.D. 19.5
S.D. 22.5
NEB. 20.7
KAN. 24.8
OKLA. 21.6
TEXAS 28.5
MINN. 18.8
IA. 21.5
MO. 20.6
ARK. 21.4
LA. 20.3
WIS. 24.7
ILL. 22.4
MICH. 24.2
IND. 27.4
OHIO 24.5
KY. 18.2
TENN. 20.9
MISS. 19.8
ALA. 24.4
GA. 24.7
FLA. 29.8
S.C. 26.2
N.C. 19.8
VA. 24.1
W.VA. 21.2
PENN. 15.6
N.Y. 12.5
N.H. 16.6
VT. 22.2
ME. 20.1
MASS. 9.4
R.I. 7.2
CONN. 12.6
N.J. 12.6
DEL. 27.3
MD. 18.7
U.S. RATE 21.9
BELOW 20.0-13 STATES
20.0 TO 22.9 - 13 STATES
23.0 TO 28.9 - 12 STATES
29.0 & OVER - 10 STATES

(National Safety Council; based on data from state traffic authorities, National Office of Vital Statistics, and U. S. Public Roads Administration)

Motor Vehicle Deaths per 100,000 Population by States

________2. Kentucky has relatively more vehicle deaths than does Illinois.

________3. The most densely populated states as a rule have the largest relative number of vehicle deaths.

________4. The South has the best automobile drivers.

________5. Probably more people were killed by vehicles in Michigan than in North Dakota.

________6. Motor vehicle accidents are on the increase.

________7. The map does not take into account the actual number of people who live in the different states.

The Evaluation of Other Aspects of Growth

It has only been within the past few years that any attempt has been made to evaluate such aspects of growth as the elements of reflective thinking, scientific attitudes, resourcefulness, creativeness, social sensitivity, etc. The area of science as a subject has had as much or more attention by test builders in these aspects of growth than any other area of the curriculum. It is therefore appropriate that the remainder of this chapter be devoted to a consideration of some of the tests and techniques which these workers have produced for science teachers.

Among the contributions to the literature of this aspect of evaluation with particular reference to science must be mentioned the work of Curtis, Davis, Tyler, Raths, Frutchery, Hendricks, Heil, Horton, and Zechiel. There have been other contributors, but to these belong the credit for pioneering and developing the materials and techniques which are now recognized as fairly standard.

The number and diversity of instruments available for evaluation in the field of science makes the problem of understanding the materials a difficult one. There are tests on the interpretation of data, setting hypotheses, skills and techniques, application of principles, nature of proof, scales of belief, and many others. Also the techniques developed are varied and unique. It is the plan of this survey to take the different phases of the subject, one at a time, and discuss those materials and techniques which have been developed.

Discovering and defining problems. An appraisal of the abilities involved in this aspect of problem solving may be attacked in several ways.

The anecdotal record. This method consists of recording the specific situation and then describing, as exactly as possible, the behavior characteristics of the student in the situation. For example: In a class discussion of some data collected to show the effects of air and wall temperature on the comfort of a person in a room one student asked, "How do you explain the apparent fact that a person in a room where air temperature is 85 degress Fahrenheit is cold when the wall temperature is 50 degress Fahrenheit?" This situation was typical of what the teacher meant by "sensitivity" to a problem in physics and the incident was recorded by a brief note at the time.

Obviously, this is a time-consuming process and therefore certain classroom short-cuts have been devised to simplify it. For example, a note may be made in the classroom that a certain student evidenced a sensitivity to a problem in physics class during a certain period, with whatever other data is essential. At the close of the period, then, a more detailed account may be written.

Another shorthand procedure has been devised in which the names of students are placed down one side of a sheet and the abilities under observation across the top. The paper is then divided into squares by lines. This provides a square for each ability opposite each name. The presence or absence of the desired response may be recorded by means of plus and minus signs. In some schools the anecdotal technique has been developed to the point of providing dictaphones so teachers may supplement their classroom notes with a minimum of effort.

There are many opportunities in science to record observations of behavior related to the discovery and definition of problems: in the laboratory, in class discussion, on field trips, etc. Frutchey and Tyler[2] describe one situation from a biology class on a field trip as follows:

> On a recent field trip in the spring the pupils in a biology class saw a number of forsythia blossoms in full bloom. As it happened, all of the blossoms were on the lower branches of the bushes; none had developed on the upper branches. Several of the students noted this fact, but only two raised the question, "Why are all the blossoms on the lower branches?" . . . One of the students carried his question still further. "Are all forsythia blossoms on lower branches? Have the lower branches been protected from the recent cold weather?" This illustrates the ability to define some of the more specific questions which need to be answered in order to solve the more general problem.

The principal difficulty of the anecdotal record technique is one of carefully defining in advance desirable or undesirable student behavior. Unless the teacher uses extreme care in making the expected behavior explicit in his own mind, very often irrelevant evidence is obtained and many relevant situations are missed. Another pitfall of the anecdotal record technique is that often a teacher tries to use it to gather evidence concerning pupil achievements in too many objectives. It has been found that five or six different specific behaviors to be watched for is the maximum addition which can be made to the routine teaching duties.

The essay type. The more usual type of essay question, with specified situations, may also be used to secure evidence of the students' ability to discover and define problems. The following situation[3] illustrates how a question may be directed to obtain such evidence:

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[2] Frutchey, Fred, and Tyler, Ralph, "Examinations in the Natural Sciences." *The Construction and Use of Achievement Examinations,* Houghton Mifflin Co., Boston, 1936, p. 235.

> A farmer has a flock of chickens. He noticed that some days he would get many eggs and on other days he would get very few eggs. What information must you have before you can tell why there was a difference?

The training of young people in the ability to define problems and the evaluation of their achievement may go along together. For example, after a unit or topic for investigation has been selected, the teacher may plan an activity in which an over view of the unit is given. This may be in the form of a mimeographed introduction, a talk by the teacher, or even informal discussion with the group. The students may then be instructed, as an assignment, to bring in the questions or problems growing out of the activity. The range and quality of the problems proposed will give a rough measure of the students' sensitivity to problems as well as their ability to define problems.

The mixed response. Frutchey and Tyler[4] suggest still another way in which some indication of this ability may be obtained. In this technique the statement of a broad problem is followed with a list of minor questions or problems which must be solved. Mixed in with the relevant questions are some which might be associated with the major problem but which do not bear directly upon it. The students are asked to check the problems in the list which must be answered before the major problem can be solved. Again, this is a device that may be used not only for evaluation, but for instruction as well.

Collecting information bearing on the solution of a problem. This step in solving problems involves a large group of fundamental skills which are ordinarily considered to be outside the concern of the science teacher. That the science teacher must be concerned with certain of those skills basic to obtaining information bearing on problems is obvious when one considers, for example, that a large part of the students' information comes from reading. Among the skills involved is the use of the library and reference books as well as the specific reading skills. Accordingly, the science teacher must assume responsibility for providing remedial instruction in those skills when they do not require the attention of a special teacher. In assuming this responsibility, he should take advantage of those instruments of evaluation which will discover most effectively the specific causes of difficulties.

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[3] *Ibid.*

[4] *Ibid.*

The limitations of space will not permit a detailed discussion of the tests available for evaluating the several special abilities involved. It should be noted, however, that several of the general tests, such as the Iowa Placement Examinations, contain sections devoted to reading abilities in science.

Several rather simple techniques may be used by the science teacher to discover certain fundamental difficulties in reading. This is especially true of the younger boys and girls studying general science. Individuals may be asked to read aloud during a supervised study period. Often this will reveal the word readers as contrasted with those who read phrases. Another way to discover the slow readers is to start everyone reading a given passage and time them. Comprehension may be roughly evaluated by following a period of concentrated reading with a group of test questions based on the passage read.

Many students experience great difficulty with the vocabulary of science. Single tests on the definition of new words in reading passages will serve not only to keep students alert to the use of glossaries and the dictionary but will sort out the words which are causing the greatest difficulty and enable the teacher to give special instruction in them.

The efficient use of books and library facilities makes for much more effective problem solving. The test, "The Use of the Library for High School"[5] by Reed, is probably the best instrument available at present for evaluating the techniques and skills involved. Familiarity with reliable sources of information has been considered by many teachers as an important element in developing problem-solving ability in young people. Frutchey and Tyler[6] have worked out and described a way for collecting data on this point. A list of questions such as the following is prepared:

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[5] Reed, Lulu R., test on "The Use of the Library for High School," Bureau of Educational Research, Ohio State University, Columbus, Ohio.

[6] *Op. cit.*

(1) Where could you find out about the general principles which help to explain the methods of sending pictures by wire?
(2) Where could you locate the relative electrical conductivity of iron, copper, aluminum?
(3) If you were making a special report on the corpuscular theory of light, where would you get helpful information?

In response to these questions, it is expected that the student will be as definite as possible, mentioning the names or titles of books, magazines, and newspapers. If the student is unable to be so specific as to give these, he is asked to tell how he would locate the book, magazine, or newspaper which contained the information.

It is essential that students learn to evaluate their sources of information. The Science Committee of the Wisconsin Education Association[7] has prepared a series of tests for evaluating this aspect of problem solving in general science, biology, physics, and chemistry. The tests are made up of a series of items from each field "which represents beliefs, opinions, and facts which either are, or once were, accepted as being true." The individual is asked to judge each of these items as belonging to one of the following stages in the development of exact knowledge:

(1) Superstitious belief stage.
(2) Authoritative opinion stage.
(3) Observation stage.
(4) Controlled experimentation stage.

Certain kinds of information in problem solving must be collected by observation and experiment. Students vary greatly in their ability to observe accurately, and many teachers consider this ability an important outcome to be evaluated. Even a small amount of training in this skill will produce measureable results. It is not essential that exact instruments of evaluation be used for this, since the chief purpose is diagnosis for subsequent remedial instruction. In the Biology Department of the Central High School of Tulsa, Oklahoma, demonstrations followed by mimeographed sets of "best answer" questions have been used both for purposes of evaluating and developing the ability to observe accurately.

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[7] Science Committee of the Wisconsin Education Association, Insurance Building, Madison, Wisconsin.

The anecdotal method may again be used in recording information on the ability to observe. Data obtained on field trips, in the laboratory, and from other sources may well be noted in such a record.

The Science Committee of the Wisconsin Education Association[8] has developed a test of "Controlled Experimentation," in which a series of experimental problems are described with respect to the factors involved. The student is asked to check in each case which factors were varied, which were kept constant, and which produced the observed difference.

The analysis of pupil's work products may provide a very useful basis for evaluating growth in the skills needed for collecting evidence. Such work products may include (a) written and oral reports, (b) collections of pertinent materials, (c) written laboratory reports, (d) workbook products, (e) notebooks, (f) apparatus set-ups, (g) drawings and diagrams, etc. It should be noted that these work products do not provide a basis for evaluation unless the activities which produce them have been planned with the intent of evaluation in mind. A few examples will show how certain types of pupils' work products may be used for purposes of evaluating learning.

Sample 1. *Analysis of specified apparatus setups.* Evidence with respect both to the manipulative skills possessed by pupils and to their understanding of the requirements of appropriate experimental apparatus is to be had by examining the way in which they assemble apparatus for prescribed experiments. No elaborate procedure is called for. A simple check list with an appropriate system of symbols suffices. The names of pupils may be listed in a column at the left on a sheet of paper. Parallel columns at the right should be headed by the criteria to be used in evaluating the apparatus. Suggested headings are:

(1) Selection of proper items of equipment.
(2) Assembly in most direct and economical order.
(3) Neatness of setup.
(4) Stability of assemblage.
(5) Promptness in finding needed parts and in assembling the apparatus as a whole.

Sample 2. *Analysis of original apparatus setups.* Beauchamp and

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[8] These examples have been used with the permission of the publishers of the *Forty-Sixth Yearbook* of the National Society for the Study of Education.

Webb[9] have reported a series of laboratory situations by means of which pupils' resourcefulness in the use of apparatus may be tested. (The same situations may be dealt with in the form of paper-and-pencil tests, in which case each situation is described, and the pupil writes out his plan of action.) A few illustrative situations appear below:

(1) Given: Bunsen burner, fastened down; gas supply; matches; short rubber tubes; glass tubes.
Required: To light the Bunsen burner without moving it.

(2) Given: Two bottles of odd shape, nearly the same in size; pan of water.
Required: To find which bottle holds the more.

(3) Given: A mixture of sugar, sand, and iron filings; also some water; magnet; towels.
Required: To separate each of the three substances in the mixture from the other two.

(4) Given: One pound of sand; paper towels; one balance (no weights).
Required: To secure accurately 4 oz. of sand.

Sample 3. *Evaluation of typical reports of experimental work.* Not uncommonly pupils are required to prepare written reports of their experiences in the laboratory for no apparent purpose other than to provide "busy work." Under such conditions the opportunities for evaluation which are inherent in these reports are wasted. On the other hand, the grading of pupil reports for the purposes of evaluation which are inherent in these reports are wasted. On the other hand, the grading of pupil reports for the purposes of evaluation can easily become a laborious task, so much so as to discourage teachers from the attempt at all. What is needed is a simple procedure which will supply pertinent evidence with a minimum of effort on the teacher's part.

The use of a check list is recommended. First, the teacher should give his pupils clear and complete information concerning the content expected in reports and the form in which it should appear (perhaps an outline of topics). Then as the reports are read, entries can be inserted by symbols in a special check list. The names of the pupils appear in a column at the left. Parallel columns are headed by the criteria to be used in evaluation, these criteria having been previously explained to the pupils. Suggested criteria, which can be abbreviated on the check list, are:

(1) Is the laboratory problem clearly stated?
(2) Is the experimental factor correctly identified and manipulated?
(3) Is the experiment adequately controlled?
(4) Are the data within the limits of error to be expected in view of the equipment used?

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[9] Beauchamp, R. O., and Webb, H. A., "Test of Laboratory Resourcefulness," *School Science and Mathematics,* XXII and XXVII, Mar. 1922 and May 1927.

(5) Are the data correctly organized and recorded?
(6) Is the interpretation of data reasonable?
(7) Is the conclusion consistent with the statement of the problem and with the data obtained?

Sample 4. *Evaluation of reports simplified for particular purposes.* Sharpe[10] describes a unique plan for reporting experiments which enables the teacher (and the pupil) to concentrate upon designated elements of growth. Follows is an adapted sample report, with the facts entered in parentheses as they might be supplied by a pupil:

Interpreting evidence and drawing inferences in the solution of problems. The evaluation of the ability to interpret data has been given careful study by the Evaluation Staff of the Commission on the Relation of School and College.[11] The results of their studies seem to indicate that student achievement in the ability to inter-

SCIENTIFIC METHOD EXPERIMENT SHEET

Date: ____ (March 4, 1949) ______ Name: ___ (John Smith) ________

Question: ______ (Does aspirin keep cut flowers longer?) ____

Main Drawing		Control Drawing	
Main Steps (I mounted some freshly cut flowers in water containing aspirin, as shown above, and observed them four times a day.)	Main Observations (Flowers faded noticeably on the third day.)	Control Steps (I mounted some freshly cut flowers in ordinary water, as shown above, and observed them four times a day.)	Control Observations (Flowers faded noticeably on the third day.)
Answer (No; aspirin did not keep these cut flowers fresh longer.)	Because (the aspirin-tested flowers faded just as quickly as the untreated flowers).		
	The control shows (that there was nothing to affect the duration of the aspirin flowers that would not also affect the untreated flowers, except the aspirin. There were no other variables).		

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[10] Sharpe, Phillip B., "Why Not Use Control Experiments," *Science Education* XXII, January 1938.

[11] Evaluation Staff of the Commission on the Relation of School and College of the Progressive Education Association, The University of Chicago, 6010 Dorchester Avenue, Chicago.

pret data depends upon a pupil's knowledge of certain principles involved. These may be stated as follows:

(1) An interpretation can be made from the data without qualification, when it involves an accurate comparison of two or more points in the data.

(2) An interpretation involving a calculation that can be made directly from the data can be supported or contradicted by the data alone, depending upon the accuracy of the calculations.

(3) An interpretation going slightly beyond the data, but in agreement with the trend, must be qualified as "probably true." (Extrapolation)

(4) An interpretation going beyond the data, and contrary to the trend revealed, must be qualified as "probably false."

(5) An interpretation referring to a point within the data, but not specifically described, must be qualified as "probably true" or "probably false," depending upon whether it does or does not agree with the revealed trend. (Interpolation)

(6) An interpretation going beyond the data in assuming that things, conditions, processes, and so forth, which are alike, is based upon "insufficient evidence."

(7) An interpretation assuming the presence of a predetermined plan in nature or purpose must be qualified as being based upon "insufficient evidence."

(8) An interpretation assigning a cause to the relationships revealed by the data, and when not supported by other evidence, must be qualified as being based upon "insufficient evidence."

(9) An interpretation involving an ambiguous use or misuse of a term in the data must be qualified by relating it to the specific "new" use.

(10) An interpretation assuming that what is true of a single case, or of a few cases, is true of all cases, must be qualified as being based on "insufficient evidence."

(11) An interpretation involving a personal judgment, sometimes biased, at other times unbiased, which is external to the data, must be qualified as being based upon "insufficient evidence."

(12) An interpretation representing a universal generalization, concerning which the data presented serve only as a single illustration, must be qualified as being based upon "insufficient evidence."

Horton,[12] working at Ohio State University, analyzed the responses made by students on interpreting data into ten types. Such an analysis of student responses is extremely useful for setting situations in the classroom for further instruction and practice in the abilities involved in interpreting data. His analysis is given below:

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[12] Horton, Clark, "A Comprehensive Testing Program for Biology," Doctor's Dissertation unpublished, Ohio State University, Columbus, Ohio, 1937.

Classification of student responses:

(1) Interpretations supported by the data.
(2) Interpretations contradicted by the data.
(3) Unwarranted extensions of the data by interpolation or extrapolation.
(4) Teleological explanations.
(5) Unwarranted conclusions as to cause and effect.
(6) Interpreting multiple effects as cause and effect.
(7) Unwarranted interpretations that go beyond the data given.
(8) Repetition of data without drawing significant inferences.
(9) Valid inferences using only part of the data.
(10) Valid inferences based on all the data.

The following examples represent situations in a test on "Interpretation of Data,"[13] devised by the Evaluation Staff of the Commission on the Relation of School and College.[14]

Directions: A test, an experiment, or a situation is indicated in each of the following exercises. Below the description is a list of several statements, suggested as possible interpretations of the data. Assume that the statements are accurate. Carefully consider each of them and indicate whether you believe that the evidence:

(1) Is sufficient to make the statement true.
(2) Suggests that the statement is probably true.
(3) Is sufficient to make a decision concerning the statement.
(4) Suggests that the statement is probably false.
(5) Is sufficient to make the statement false.

Sample No. 1.

Professor Arthur Hershey of McPherson College has carried on some interesting experiments concerning the survival of white rats in various types of atmospheres. Ordinary air has the following composition:

Nitrogen	77.87%
Oxygen	20.94%
Argon	.94%
Water vapor	.22%
Carbon dioxide	.03%
Traces of helium, xenon, and krypton	

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[13] P.E.A., Test on Interpretation of Data.

[14] *Op. cit.*

Professor Hershey varied the percentage of oxygen and nitrogen as well as the other gases present in our atmosphere and noted the reaction of the rats in the artificial atmosphere. The following are his observations:

(a) Ordinary percentage of oxygen and nitrogen with other gases missing—supported the life of the rat only a few days.
(b) Pure oxygen, no other gases present—supported life from two to five days.
(c) Ordinary composition with helium replacing nitrogen—supported life in a manner similar to ordinary air.
(d) Ordinary composition with argon replacing nitrogen—supported life only a few days.
(e) A 25% oxygen, 75% argon mixture with all other gases missing—supported life better than the ordinary atmosphere, the rats seemed to be more energetic and apparently suffered no ill effects.

Statements:

(1) When exposed to an atmosphere which contained no nitrogen, a gas which makes up almost 80% of ordinary air, the rats were more active than in ordinary air and apparently suffered no ill effects.
(2) Carbon dioxide and traces of helium, xenon, and krypton were necessary for the existence of the white rats.
(3) The percentage of the gases present in the atmosphere is not the most important atmospheric factor in maintaining the life of the rats.
(4) People should not subject white rats to conditions other than those which nature intended for them.
(5) The white rats died within two to five days in an atmosphere of pure oxygen due to the fact that oxidation occurred at such a rapid rate that tissues were consumed.
(6) Nitrogen must be present in the atmosphere if white rats are to survive.
(7) Professor Hershey performed these experiments in order to see if he could suggest a better atmosphere for human beings.
(8) Human beings, just as white rats, would be more energetic and suffer no ill effects if placed in an atmosphere of 25% oxygen and 75% argon.
(9) When rats are subjected to an atmosphere of ordinary composition, but containing a high percentage of water vapor, they are less active than when the atmosphere contains a comparatively small percentage of water vapor.
(10) Gases present in the ordinary atmosphere in a very small percentage play an important part in the maintenance of life in white rats.

Sample No. 2.

In the chart on page 207 some data concerning feeble-mindedness are presented:

Statements:

(1) The mating of Martin, Sr. with a nameless feeble-minded girl during the Revolution resulted in a line in which the children were predominantly feeble-minded.

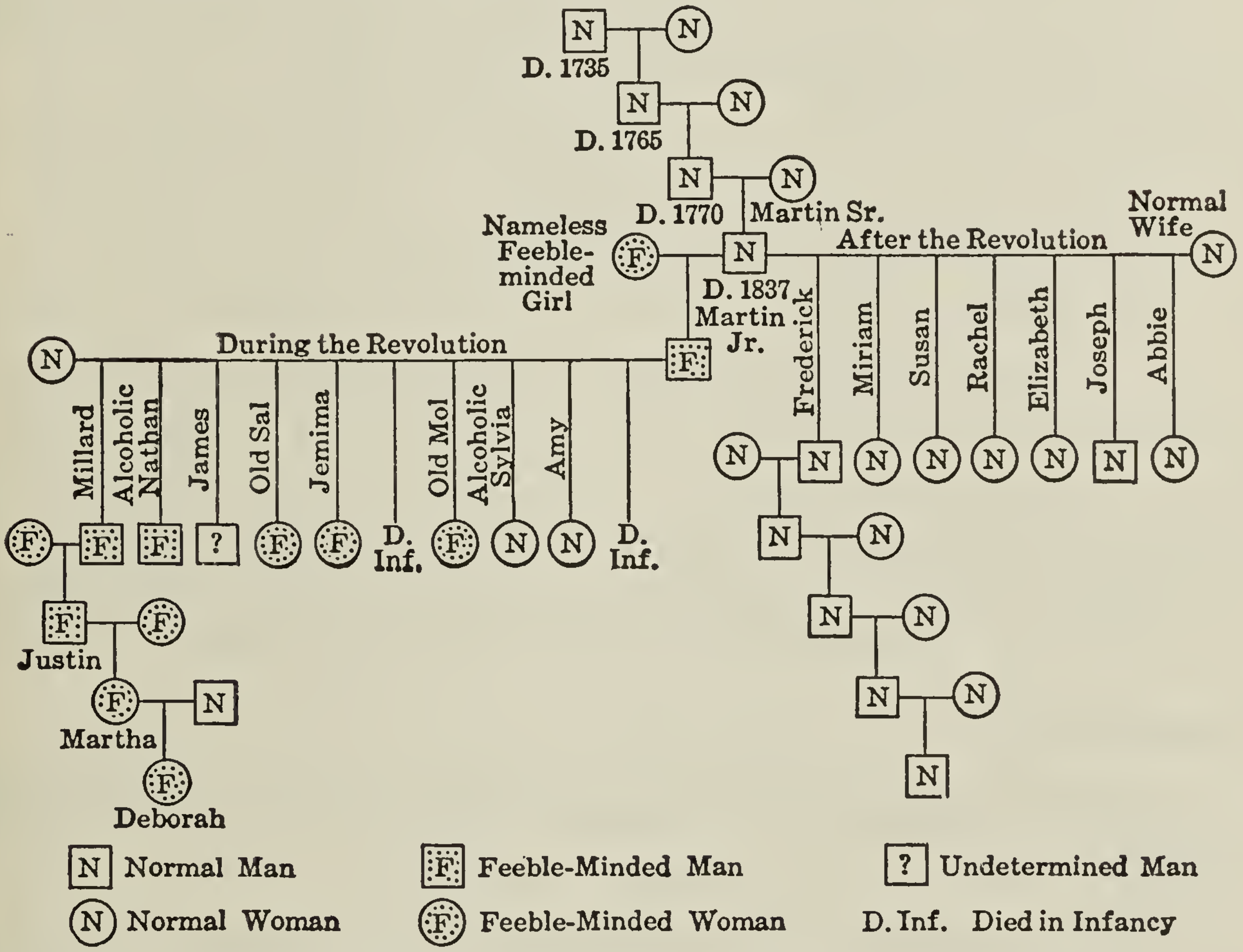
(2) Martin, Sr's marriage to a normal woman after the Revolution resulted in a line in which there were several feeble-minded children.

(3) When a normal person marries a feeble-minded person, a large proportion of the children may be feeble-minded.

(4) A large proportion of the children born when two normal people marry may be feeble-minded.

(5) Just as feeble-minded children may be born when a normal person marries a feeble-minded person, so will children born in families in which the parents are drunkards be alcoholics in the greater proportion of such marriages.

(6) About four times as many feeble-minded as normal children were born in the line which resulted from Martin, Sr.'s marriage to the nameless feeble-minded girl.


N
N
D. 1735
N
N
D. 1765
N
N
D. 1770
Martin Sr.
Nameless Feeble-minded Girl
F
N
After the Revolution
Normal Wife
N
D. 1837
Martin Jr.
F
During the Revolution
N
Millard
Alcoholic Nathan
James
Old Sal
Jemima
Old Mol
Alcoholic Sylvia
Amy
Frederick
Miriam
Susan
Rachel
Elizabeth
Joseph
Abbie
F
F
F
?
F
F
D. Inf.
F
N
N
D. Inf.
N
N
N
N
N
N
N
N
F
F
Justin
N
N
F
N
Martha
N
N
F
Deborah
N
N Normal Man
F Feeble-Minded Man
? Undetermined Man
N Normal Woman
F Feeble-Minded Woman
D. Inf. Died in Infancy

(7) Feeble-mindedness is solely due to inheritance from parents.

(8) The children born in the line which resulted from the marriage of Martin, Sr. to a normal woman became outstanding leaders in community affairs.

(9) Feeble-minded persons tend to marry feeble-minded persons, and normal persons tend to marry normal persons.

(10) The birth of feeble-minded persons is not beneficial to society.
(11) Had the children who died in infancy lived, they would have been normal men or women.
(12) If Jemima, feeble-minded daughter of Martin, Jr. and a normal woman, had married a normal man, none of their children would have been feeble-minded.

A test made up of problems like the samples cited above is valuable for instructional purposes as well as for measuring student achievement in the ability. For such tests the Evaluation Staff of the Commission on the Relation of School and College have worked out a summary and tabulation sheet.[15] From this summary of a student's performance on a test of "Interpretation of Data," it is possible to get the following information:

(1) His general accuracy in judging the interpretation in the test.
(2) His general accuracy in judging only those statements which must be qualified as probably true or probably false.
(3) His general accuracy in recognizing only those statements which in reality have insufficient data to support them.
(4) His general accuracy in recognizing only those statements which are obviously true or obviously false.
(5) His general tendency to err in the direction of understatement.
(6) His general tendency to go beyond the data.
(7) His general tendency to make crude errors in judgment.

If a teacher has such evidence before him on any particular student, it is possible to plan with that student a program of effective remedial work. There is a psychological factor involved in learning which follows a diagnostic test. The student is usually pent up with the desire to improve his performance and is thus possessed of a drive not usually present in the classroom situation.

Sample No. 3.[16]

Another form of the test on "Interpretation of Data" in which only three types of responses are expected is illustrated by the following problems:

Directions: In each of the following exercises, an experiment is described. Below the description of the experiment are several statements which have been suggested as interpretations of the experiment. Assume that the facts given in the description of the experiment and in the results obtained are correct, then on the basis of these facts only, consider each statement.

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[15] Evaluation Staff of the Commission on the Relation of School and College, "Interpretation of Data." Explanation of the Summary Sheet and Tabulation Sheet. P.E.A. 2761, Test 2.5, 6010 Dorchester Avenue, Chicago, Ill.

[16] *Ibid.* P.E.A., Test 60.

Mark with an R—every statement which is a reasonable interpretation of the results obtained.
U—every statement which might possibly be true but for which insufficient facts are given to justify the interpretation.
F—every statement which cannot be true because it is contradicted by the results obtained in the experiment.

In an experiment some white starch was treated with brown iodine solution. This was done ten times, and each time a blue color was formed.

Later some white starch was mixed with saliva. The mixture was left for a time and then treated with brown iodine solution. This was done ten times and each time no blue color was formed. Assume that saliva does not change the iodine solution.

(a) The starch was changed to sugar by the action of saliva. (U) a.
(b) Saliva digested the starch........................(U) b.
(c) Starch acted upon the iodine......................(R) c.
(d) Saliva produced a change in the starch..............(R) d.
(e) Starch mixed with iodine solution did not turn blue....(F) e.

Sample No. 4.[17]

R—Reasonable interpretation of the results obtained.
U—Interpretation might be true, but insufficient facts are given to justify it.
F—Interpretation contradicted by the results obtained.

An approximate distribution of energy in the infra-red, visible, and ultra-violet portions of the radiation of different sources of light, expressed in percentages, is shown in the table below.

PERCENTAGE OF TOTAL ENERGY OF VARIOUS LIGHT SOURCES

	Sunlight	Carbon arc	Incandescent Lamp	Quartz Mercury Arc
Infra-red (heat)	78	85	90	52
Visible	15	10	9	20
Ultra-violet	7	5	1	28

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[17] *Ibid.* P.E.A., Test 62.

(a) Most of the energy of sunlight is available as visible light. . . . ( ) a.
(b) The carbon arc releases a larger portion of energy as ultra-violet light than does any of the other sources. . . . . ( ) b.
(c) Less than 10% of the energy furnished by an incandescent electric lamp is used in giving off visible light. . . . . ( ) c.
(d) The quartz mercury arc furnishes a larger proportion of energy as ultra-violet light than does the sun. . . . . ( ) d.
(e) Most of the energy of all the sources of light listed is given off as heat or "infra-red" rays. . . . . ( ) e.
(f) The quartz mercury arc is more effective for health treatments than sunlight. . . . . ( ) f.
(g) On a cloudy day the proportion of total energy in the form of ultra-violet light from sunlight is less than 7%. . . . . ( ) g.

Sample No. 5.[18]

Directions: In each of the following exercises, an experiment is described. Below the description of the experiment are several statements which have been suggested as interpretations of the experiment. Assume that the facts given in the description of the experiment and in the results obtained are correct, then on the basis of these facts only consider each statement.

Mark with a 1—every statement which is a reasonable interpretation of the results obtained.
2—every statement which might possibly be true but for which insufficient facts are given to justify the interpretation.
3—every statement which cannot be true because it is contradicted by the results obtained in the experiment.

1. Hydrogen gas under a pressure of 25 atmospheres was bubbled through water at a temperature of 25° C. The number of cc. of hydrogen, at standard conditions of temperature and pressure dissolved per gram of water at 25° C. was found. This was done ten different times and the average number of cc. of hydrogen at standard conditions per gram of water at 25° C. was calculated.

The same procedure was followed in finding the average number of cc. of hydrogen at standard conditions dissolved per gram of water at 25° C. but under different pressures. The results are given in the following table:

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[18] Taken from "Cooperative Chemistry Test," Part II, Ohio State University, Columbus, Ohio.

Atmospheres of Pressure	Average Number of CC. of Hydrogen per Gram of Water
25	.44
50	.87
100	1.73
200	3.39
400	6.57
800	12.46
1,000	15.20

(a) As the pressure was increased the amount of hydrogen dissolved in the water was decreased...................... ( ) a.
(b) Raising the temperature of the water decreases the amount of hydrogen the water will dissolve.................... ( ) b.
(c) Hydrogen will not dissolve in water at the pressures used in this experiment..................................... ( ) c.
(d) At 2000 atmospheres of pressure the amount of hydrogen dissolved is greater than at 1000 atmospheres.......... ( ) d.
(e) As the pressure was increased from 25 to 1000 atmospheres the amount of dissolved hydrogen was increased.......... ( ) e.
(f) Each time the pressure was doubled the amount of hydrogen dissolved in the water was more than doubled.. ( ) f.
(g) Stirring the water decreases the amount of hydrogen which will dissolve in the water............................. ( ) g.
(h) More hydrogen will dissolve in the water in 2 hours than in 1 hour... ( ) h.

It should be pointed out at this point that the test on "Interpretation of Data" made up of problems of the three-response type are not as valid as tests made of problems of the five-response type cited earlier. It has been found, however, that these three-response tests are particularly useful at the levels below the senior high school. In fact, they have been used down as far as the fifth grade for measuring the ability to interpret data.

The Science Committee of the Wisconsin Education Association[19] has developed a series of tests on "Cause and Effect Relationships" which give evidence on the ability of students to distinguish between cause and effect and to establish causes for observed effects. Below are given the directions and several sample items selected from these tests.

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[19] Science Committee of the Wisconsin Education Association, *op. cit.*, "Cause and Effect Relationships Test in Science," Form A.

Directions: This is a test of your ability to distinguish the cause-and-effect relationships between paired occurrences. Each item of the test consists of two such paired occurrences which have occurred or do occur approximately together. So far as time is concerned, one might be the cause of the other. Each pair can be classified under the headings A, B, C, D, or E, which are given below and at the top of each page of the test. You are to classify the items by checking in the corresponding column as shown in the example.

	A	B	C	D	E
A. The first is practically the sole cause of the second....................	x				
B. The first is one of a number of important contributing causes of the second..........................		x			
C. The first contributes only slightly to causing the second..............			x		
D. Both are results of the same general cause or causes..................				x	
E. The first bears no causal relationship to the second...............					x

EXAMPLES:

	A	B	C	D	E
The branches of a tree wave to and fro; a nearby windmill turns......				x	

Sample Items:

(a) A woman found a four-leaf clover; that night she held good cards at bridge.
(b) An electric circuit was closed; lights on the circuit lighted.
(c) The sun shines on leaves of a plant; carbohydrates are manufactured in the leaves.
(d) The weather suddenly becomes colder; moisture collected on the inside of the windows.
(e) A tire blew out; the car went into the ditch.
(f) A telephone wire was being used for conversation; the wire hummed.
(g) A man working in the sun did not perspire; he was overcome by the heat.

The Science Committee[20] of the Wisconsin Education Association, in an attempt to determine the characteristics exhibited by a person having a scientific attitude of mind, found that the ability to distinquish between fact and theory was rated high as one of the elements by science teachers consulted in the study. On the basis of the evidence of this study the committee developed a test designed to evaluate the ability of high school students to distinguish between fact and theory. This test has been through several editions and has been given to several hundred students in the high schools of Wisconsin. There are one hundred items in the test. Below are given the directions for the test, an example, and several items selected at random.

Directions: This is a test of your ability to distinguish between fact and theory. The items of the test are statements which can be classified under the headings A, B, C, or D. Shown below and at the top of pages two and four of the test, you are to classify each individual item by checking in the corresponding column as shown in the example.

	A	B	C	D	E
A. Statements of well-established facts.	x				
B. Statements of well-established theories generally accepted by authorities.		x			
C. Statements of theories which are questioned by some authorities. . . .			x		
D. Statements of popular beliefs held by some people but not supported by evidence.				x	
					x

EXAMPLE:

	A	B	C	D	E
The earth receives light from the sun.	x				

Sample Items:

(a) The pressure of water varies with the depth.
(b) Fish is better brain food than bacon or other meat.
(c) Two molecules of hydrogen unite with one molecule of oxygen to form two molecules of water vapor.

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[20] *Ibid.*, "Fact-Theory Test in Science," Form A.

(d) In a bar magnet, each molecule is a magnet.
(e) The moon has no atmosphere.
(f) Lake Michigan was formed by glacial erosion.
(g) All life comes from previously existing life.
(h) Flat, blunt fingers indicate a tendency to steal.

It should be pointed out that considerable difficulty may be experienced in designing an acceptable scoring key for such a test as the one sampled above. At best such a key can only represent the opinion of the group making up the key.

It is basically essential that young people living in a chaos of propaganda, quacks, spurious advertising and the like gain facility in the skills and abilities that will enable them to successfully combat such influences as they attempt to solve their problems.

Magazines, the radio, and the movies are agencies which constantly confront young people with problems of the above type. The school must assume responsibility for training the youth of today to think logically, to recognize and evaluate assumptions, and to distinguish fact from theory. It is desirable therefore to attempt to evaluate growth in these abilities.

The Evaluation Staff of the Commission on the Relation of School and College[21] have worked out certain techniques for securing evidence on the ability of students to distinguish between facts and assumptions, to recognize those most important assumptions basic to a conclusion, to develop a logical proof, and support conclusions with sound arguments. A sample problem taken from one of these tests[22] will illustrate the use of the techniques developed.

ARE YOU LEARNING TO RECOGNIZE AND EVALUATE ASSUMPTIONS?

A small piece of magnesium will ignite and burn with a bright light in an atmosphere of chlorine gas, leaving white ashes. Bill secured some chemicals, which when mixed together and heated, gave off a colored gas. He collected some of this gas in a bottle. The chemistry teacher gave him a small piece of magnesium. Bill put it in the bottle of colored gas. The magnesium ignited, burned with a bright light, and left white ashes. Bill told his friends that his results conclusively proved that the colored gas was chlorine.

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[21] *Op. cit.*

[22] *Op. cit.,* "Nature of Proof," P.E.A., Test 5.2A.

Fact	Assumption

LIST OF STATEMENTS

(a) Chlorine is not the only gas in which magnesium will ignite, burn with a bright light, and leave white ashes. ______ a.

(b) The material the chemistry teacher gave him was magnesium. ______ b.

(c) Chlorine gas is the only gas in which magnesium will ignite. ______ c.

(d) Chlorine gas is the only gas in which magnesium will ignite, burn with a bright light, leaving white ashes. ______ d.

(e) Bill mixed and heated some chemicals which gave off a colored gas. ______ e.

(f) A small piece of magnesium will ignite and burn with a bright light in an atmosphere of chlorine gas, leaving white ashes. ______ f.

(g) The colored gas must be chlorine. ______ g.

(h) Chlorine gas is the only gas in which magnesium will burn with a bright light. ______ h.

(i) Bill collected some of the colored gas in bottle. ______ i.

(j) The properties of the colored gas in the bottle were the only cause of the magnesium igniting, burning with a bright light, and leaving white ashes. ______ j.

(k) Bill put a small piece of magnesium in the bottle. ______ k.

(l) The properties of the colored gas in the bottle were not the cause of the magnesium igniting, burning with a bright light, and leaving white ashes. ______ l.

(m) The magnesium ignited, burned with a bright light, and left white ashes. ______ m.

Part 1. *Directions:* All of the statements below are related in some way to the problem which has been stated. Suppose for the moment that you personally had been present in the problem. Under those circumstances you would probably accept some of the statements of matters of fact, others of them you would regard as assumptions. By assumption we mean a statement that is open to doubt; one that may or may not be true and which in this particular situation would not be acceptable as a fact. Of the statements below, which do you regard as assumptions and which as matters of fact? Place a check mark in the appropriate column before the statement.

Part 2. *Directions:* Read over again only those statements marked as ASSUMPTIONS. Place a check mark after those TWO ASSUMPTIONS which are absolutely necessary in proving that the gas was chlorine. Do not mark more than two.

ARE YOU LEARNING HOW TO DEVELOP A LOGICAL PROOF?

When arguments for or against some proposition are presented in newspapers, magazines, speeches, or textbooks, we often feel that the discussion could have been made more logical. Authors sometimes put in statements that are really unnecessary to prove their point; at other times they leave out important arguments; on still other occasions they arrange their statements in such poor order that the conclusion does not seem to be based on or to grow out of the arguments.

Part 3. *Directions:* Suppose you were describing this experiment in order to prove that chlorine gas was collected. What are all of the absolutely necessary steps in the complete development of the proof? Use as many of the above statements as are necessary and place the letters of these statements in their proper order on the line below. Do not use any unnecessary statements.

ARE YOU LEARNING TO SUPPORT YOUR OWN CONCLUSIONS WITH SOUND ARGUMENTS?

Part 4. *Directions:* In Part 3 of this test you presented a logically developed proof which reached the conclusion that the colored gas Bill made must be chlorine. You may or may not believe that it has been adequately proved that the colored gas must be chlorine. Check the following statement which best represents your own personal opinion as to the nature of the gas.

________a. I believe that the colored gas Bill made was chlorine.
________b. I do not believe that the colored gas Bill made was chlorine.
________c. I do not believe that it has been adequately proved that the colored gas Bill made was chlorine.

Write out the reasons you have to support your opinion.

A bulletin prepared by a group of science teachers working at the 1937 Summer Workshop of the Progressive Education Association[23] contains many tests contsructed to evaluate student ability to recognize and evaluate assumptions. Any person interested in this aspect of evaluation in science will find many helpful suggestions as to technique and type situations by consulting this excellent monograph.

Frequent classroom testing with situations of this sort should enable the teacher to readily discern those students who need help in distinguishing between fact and assumption. Also the class discussion of the results of such a test after it has been scored should offer excellent teaching opportunities, as questions are raised as to why this or that answer was or was not correct.

Setting and testing hypotheses. In Chapter 5 the several specific abilities involved in this aspect of problem-solving behavior were mentioned. There probably has been less work done on the evaluation of these abilities than on any other aspect of problem solving, and yet it is one of the most important places where evidence is needed. This is true because setting and testing hypotheses has had little attention in so far as instruction in science is concerned, and therefore teachers need tests for finding out the extent to which the abilities are present or absent before very much can be done in developing them.

It is possible to secure a very rough idea of the ability of students to test hypotheses by making up a test such as the following:

Directions: Below and on the following pages are some statements which some people think are true and some people think are false. Describe the procedure which should be followed in finding out whether or not the statement given is true.

Always describe the best way that you can think of for testing the truth of the statement given. Write your answer in the blank space below the statement. If you need more space for any answer, use the other side of the page.

The following sample shows you what you are to do.

Sample. *A light iron ball falls as rapidly as a heavy iron ball.*

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[23] Progressive Education Association Summer Workshop, "Materials Prepared by Participants in the Science Group," Progressive Education Association Evaluation in the Eight-Year Study, University of Chicago, Chicago, Ill.

To find out whether this statement is true or false one might drop two iron balls of different weights from a high place. The time for each to fall to the ground could be measured and written down. The balls should be the same shape and size. With such iron balls, the resistance of the air would probably be about the same on each ball. If this were not the case, the experiment should be tried in a vacuum on a smaller scale. If after a number of trials, it was found that they reached the ground at about the same time, one could feel sure that the statement made above was true.

Now you describe in detail how you would set out to discover whether the situations listed in the following were true or false.

List of Statements:

(1) Most of the material of which trees are composed comes from the soil.
(2) Tiny plants called "moulds" cause the rotting of fruits.
(3) Drinking water with one's meals retards digestion.
(4) When animals grow heavy fur in the late fall, the winter will be more severe than usual.
(5) The volume of a given mass of gas varies with its temperature.
(6) When taking a picture of an object with a camera, the farther the object is from the lens, the smaller will be its image on the camera film.
(7) The red color of most rocks and soil is due to the presence of the element iron in these rocks or soil.
(8) The daily range in temperature is greater at inland places than at places on the shores of large bodies of water.
(9) Trout do not occur in many streams because the temperature of the water is too high.
(10) A certain species of fungus which is found in many dead or dying elm trees causes the death of these trees.
(11) Reforestation reduces the danger of floods.
(12) Chemical actions are speeded up by applying heat.
(13) One can tell whether or not a substance is starch by treating it with iodine solution. If the substance turns blue it is starch.
(14) Destruction of the small green plants called "algae" in lakes and streams reduces the fish population.
(15) Dogs would die if kept in an atmosphere of pure oxygen for an hour.
(16) Rats instinctively refuse to eat poison.
(17) Weeds reduce the yields of crops because the weeds take away from the soil the mineral matter required by the crops.
(18) Green plants use the nitrogen of the air as a source of nitrogen for their growth.

(19) Plants lose water into the air through their leaves.
(20) Starch forms in the leaves of plants only in the sunlight.

The above list of hypotheses was formulated by a group from the Evaluation Staff of the Commission on the Relation of School and College.[24]

These statements are listed not so much as a specific test within themselves, but as types of statements which may be used in constructing such a test. Obviously items should be selected which are new to pupils and in which they have had no instruction.

Frutchey and Tyler[25] have described methods for planning experiments and testing hypotheses. The following sample items will illustrate the methods proposed.

Sample Item:

How can one find out that a certain muscle in a frog's hind leg is an extensor and not a flexor?

It would need to be shown that:

(a) The muscle relaxed.................................. ( ) a.
(b) The leg did not bend when the muscle contracted........ ( ) b.
(c) The leg moved when the muscle contracted............. ( ) c.
(d) Other muscles which were not stimulated did not extend the leg.. ( ) d.
(e) The leg extended when the muscle contracted.......... ( ) e.
(f) The muscle is a striated muscle........................ ( ) f.

Procedures which would need to be used:

(g) Tie the ends of a muscle dissected from the hind leg of a freshly killed frog to the ends of a hinge................ ( ) g.
(h) Suspend the hind leg of a freshly killed frog so that the leg is free to move in both directions...................... ( ) h.
(i) Stimulate the muscle with an electric current............ ( ) i.
(j) Examine the dissected muscle under a microscope....... ( ) j.

Drawing conclusions and making generalizations. The evaluation of this aspect of problem-solving behavior has had more attention from teachers than any other single one. Since the time when laboratory reports were first introduced, science teachers have been evaluating the ability of students to draw conclusions from specific evidence. It is probably true, however, that the routine grading of experiments from the various sciences has not revealed the extent to which students made progress in the ability.

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[24] Evaluation Staff, *op. cit.*

[25] Frutchey, F. P., and Tyler, Ralph W., *op. cit.*, p. 247.

In this section an attempt will be made to show how the evaluation of the abilities involved in drawing conclusions and making generalizations may be made somewhat more objective than it can be in the grading of experiments.

One method of building tests for this ability is reported by Tyler.[26] Working cooperatively with certain subject-matter departments at the Ohio State University, he devised tests for this ability as well as other aspects of scientific thinking.

Situations were first collected which required the student to draw reasonable generalizations from specific experimental data. Many of these situations were taken from current research in various fields. One sample will show the type of situation used.

Sample Situation:

A coleus plant exposed to full sunlight became green. A similar coleus plant exposed to only red rays of light became green. A similar coleus plant exposed to only orange and yellow rays of light became green. A similar coleus plant exposed to only green rays of light became green. A similar coleus plant exposed to only blue-violet rays of light became green.

Students were asked to read the statement and then write down the most reasonable generalization which could be made from the data. The scoring of these tests was found to be rather laborious but quite objective. Further experiment and refinement has developed several short-cut techniques more easily scored and which correlate very well with the results on essay responses used at first.

One such form has been used by Koopman[27] as a part of a general test on "Steps in Problem Solving." A sample situation taken from this test will show the technique used.

Sample:

Situation B: Assume the following statements are true. A young man vacationing at a bathing beach, rented a canoe for a day. When he had paddled 500 yards off shore, the canoe upset and the young man was drowned. He held insurance covering drowning at bathing beaches. The insurance company refused to pay, claiming that he did not drown at a bathing beach.

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[26] Tyler, Ralph W., *Constructing Achievement Tests,* Ohio State University, Bureau of Educational Research, Columbus, Ohio.

[27] Koopman, G. Robert, Associate Director, Division of Curriculum Research, Michigan Department of Public Instruction, Lansing, Michigan.

Check the conclusion you think can best be drawn from the above event:
________1. The insurance company should pay the claim.
________2. We cannot decide whether the insurance company should pay the claim unless we have more information.
________3. The insurance company should not pay the claim.

Check any of the following statements you feel support your conclusions:
________a. The insurance company should pay the claim since the young man was insured against drowning at a bathing beach.
________b. The insurance company should not pay the claim since 500 yards off shore is too far to be called "at a bathing beach."
________c. The converse of a given proposition is not necessarily true.
________d. We need a clear-cut definition of "at bathing beaches."
________e. A changed definition will produce a changed conclusion although the argument from each is logical.
________f. The insurance company should not pay as the young man drowned as a result of the canoe upset.
________g. We need to know how much the claim was.
________h. If we accept the assumptions, this conclusion must follow.

Also in this area the Evaluation Staff of the Commission on the Relation of School and College have developed a test to determine whether students can apply certain principles of logical reasoning. The principles used in the test are the if-then, the use of ridicule, the indirect argument, and the need for careful definition.

Applying principles in new situations. Learning, for the most part, becomes effective only in so far as the learner is able to make use of it in adjusting to new situations. In most areas learning should result in the mastery of certain fundamental principles. The learning cycle may not be regarded as complete until the student is able to use the principles in new contexts. The study of the opinions of many teachers as well as of the responses of students to essay questions reveals that principles are commonly used either to explain some phenomenon or to predict what will happen under a given set of circumstances.

The application of principles as a goal for science instruction is not new. For many years there have been materials in the literature of the field related to the attainment of this objective. It is important that teachers have some way of evaluating the progress of students toward this objective, and therefore a part of this chapter will be devoted to a consideration of ways for measuring objectively the abilities involved.

Every science teacher interested in this aspect of evaluation should secure the following materials prepared under the direction of the Evaluation Staff of the Eight-Year Experiment of the Progressive Education Association:[28]

1. Raths, Louis E., Application of Principles, Bulletin 5.
2. Frutchery, Fred P., Application of Principles, P.E.A. Bulletin 859.
3. Zechiel, A. N., Testing Application of Principles, P.E.A. Bulletin 874.

The essay type question for testing the ability to apply principles has long been in use. An example of such questions is:

Explain why a warm, dry, windy day is good for drying clothes; or tell what will happen if acid foods are cooked in aluminum pans.

In such questions the teacher is attempting to test the ability by making use of it in explaining or predicting. In scoring answers to such essay questions, it is very difficult to be objective and also to secure evidence of the progress of students in developing the ability. It is also very hard to isolate the specific causes of difficulty so that effective remedial instruction may be applied. Further, the essay method of evaluation is cumbersome, time consuming, and limits the number of principles which may be tested in a given time.

To obviate these, and other limitations of the essay examination for evaluating this ability, the Evaluation Staff of the Eight Year Study[29] have developed an objective technique which correlates very highly (.9) with results obtained on essay questions. Two sample situations developed after this technique will illustrate the method.

Sample Situation:[30]

A motorist on a vacation in the West had his tires checked to 35 pounds at a gas station on the edge of Death Valley Desert. That evening he drove up into the mountains where he encountered snow on the road, and stopped for the night at an inn. What happened to the tires that night?

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[28] Evaluation Staff, op. cit.

[29] *Ibid.*

[30] *Ibid.* Taken from Test 1.31, "Application of Principles in Chemistry."

Directions: Choose the conclusion which you believe is most consistent with the facts given above and most reasonable in the light of whatever knowledge you may have, and mark the appropriate space on the Answer Sheet.

A. The tires on the car were flatter.
B. One of the tires, an old, thin one, blew out.
C. No change was observed in his tires.

Directions: Choose the reasons you would use to explain or support your conclusion and fill in the appropriate spaces on your Answer sheet. Be sure that your marks are in one column only—the same column in which you marked the conclusion. (You may want to refer back to the sample under Problem I.)

Reasons:

(1) As temperature decreases, the pressure exerted and the volume occupied by a confined body of air increase.
(2) It is ridiculous to think that tires do not become flatter on colder days.
(3) Just as a warm piece of metal cools on a cake of ice, so a warm body of confined air decreases in volume when the temperature is lowered.
(4) Tire manufacturers say that tires are flatter in cold weather than in hot weather.
(5) As the motorist drove from the edge of the desert up into the mountains, the temperature became lower.
(6) The air on mountains in much thinner and hence exerts much less pressure.
(7) Tires on automobiles are flatter on cold days than on hot days.
(8) When temperature decreases, the pressure of a confined body of air decreases.
(9) The pressure exerted and the volume occupied by a confined body of air remain constant as the temperature of the air changes.
(10) As the pressure of air in an expansible container decreases, the volume of the air decreases.
(11) Cold air is heavier than warm air.
(12) A body of air taken from a valley up to a mountain top would tend to adjust itself to the lower pressure of the surrounding air.
(13) If a tire becomes "soft," it is due to a leak in the tube.

Sample Situation:[31]

In digging a tunnel under a river, some men were working in a sealed compartment where the air pressure was several times as great as the air pressure on the outside. One man's shovel struck a stone causing a large spark which fell on another worker's clothing. Which of the following probably happened?

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[31] *Ibid.*

Directions: Choose the conclusion which you believe is most consistent with the facts given above and most reasonable in the light of whatever knowledge you may have, and mark the appropriate space on the Answer Sheet under Problem VII. (Disregard the spaces for Conclusions D. and E. in this problem.)

Conclusions:

A. The man's clothing burst into flames.
B. The spark went out in a few seconds.
C. A small hole was burned in the man's clothing before another worker had time to extinguish the flame with water.

Directions: Choose the reasons you would use to explain or support your conclusion and fill in the appropriate spaces on your Answer Sheet. Be sure that your marks are in one column only—the same column in which you marked the conclusion. (You may want to refer back to the sample under Problem I.)

Reasons:

(1) Remembering that temperature of gas is increased when it is compressed, one might conclude that a fire would burn more rapidly where the air pressure was high.
(2) An increase in air pressure lowers the rate of combustion.
(3) Rate of combustion increases as the amount of oxygen present increases.
(4) A tunnel worker's clothing will burst into flames when a spark comes in contact with the clothing.
(5) No one but a thoughtless person would fail to appreciate the danger of fire in a sealed compartment.
(6) Air under pressure furnishes a better draft for combustion.
(7) The amount of oxygen in a given space is measured in terms of the number of molecules of oxygen in that space.
(8) Combustion under pressure proceeds at a much more rapid rate so that complete oxidation may be accomplished in less time.
(9) Tunnel workers report that fires burn wiith amazing rapidity in compressed air compartments.
(10) A fire may be extinguished by removing the combustible material.
(11) When the air pressure in an enclosed space is increased by pumping in more air, the number of molecules of nitrogen, oxygen, and inert gases in that space is increased.
(12) An increase in air pressure has no effect on the rate of combustion.

Evaluation on the Basis of the Observation of Pupil Behavior

Thus far most of the devices proposed in this Chapter as a basis of evaluation have been of the paper and pencil type. Oftentimes pupil behavior is the most reliable evidence obtainable for appraising progress toward the goals of science teaching. All of our goals of instruction in science, as well as in other subjects, sum up to desirable behavior changes. Thus it is important that we look for evidence for purposes of evaluation within pupil behavior itself. A few examples follow of how pupil behavior may be utilized to evaluate progress toward the objectives of science instruction.[32]

(a) Informal observation

Sample 1. *An observed attitude of inflexibility.* In a class which had been reading, voluntarily and by assignment, about nuclear fission, one boy announced that he had found an error—that in a certain article the writer had referred to chemical elements numbered 93, 94, and 95. His chemistry text had told him that there are only ninety-two elements, and he therefore refused to accept the statement in the periodical. He held to this position in spite of the fact that several other children were able to cite from their reading apparently valid evidence that three new elements had been proposed.

The teacher noted the incident in an anecdotal record and described the boy's behavior. During the year at least three other similar reactions were recorded for the same boy in one class and two more in another area. This accumulated evidence, based upon observation, enabled the teacher to evaluate the boy as one who was unwilling to change his opinions in the light of new and reliable evidence. (Had it not been for other observations, which revealed the same tendency, the behavior cited might just as well have been interpreted to signify, on the boy's part, the desirable attitude of reasonable doubt in the presence of incomplete data.)

Sample 2. *An out-of-school use of scientific method.* A junior high school girl, after drinking canned orange juice for the first time, wondered about the relative cost and quality of the canned and fresh juices. Instead of asking someone for the answer to her question, she purchased a can of orange juice and as many oranges as she could buy for the same amount of money. She squeezed the orange juice and then compared this amount with that in the can. She next compared them for taste and finally came to the question of their relative values for health. This new problem led her to procure bulletins from reliable agencies.

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[32] These examples are used with the permission of the publishers of the *Forty-Sixth Yearbook* of the National Society for the Study of Education.

The mere fact that this observed behavior did not take place in school, but in the home, in no way invalidates the girl's apparent understanding of scientific method, however elementary. As a matter of fact, it could be argued that the out-of-school occurrence of the behavior in question enhanced its value for the purposes of evaluation.

Sample 3. *A long-time observation of growth toward science objectives.* A girl, one of the better students in a class, became interested in the effects of various amounts of chemical elements in the soil on the growth of plants. The girl's interest was unaffected by her inability to carry out exact experimentation in the school laboratory. Instead, she visited a local plant-research center, talked with the soil chemist there, and with his aid arrived at a definition of her problem. She secured a quantity of sand and devised a method of sterilizing it. She learned how to weigh precisely on chemical balances, for she worked with as little as a milligram of some substances. She selected her plants, devised controls and started the experiment. After about two weeks nearly all her plants were dead. She located the cause as inability to control the temperature in the growing room, designed a glass box with a top, secured a thermostat, placed light bulbs in the glass box to provide heat, and started out again. The study was carried on for more than six months, and some of the factors were studied over and over. Finally her results were checked with those of a trained research worker and found to be reliable.

Over this period of several weeks the instructor had innumerable opportunities to note significant behavior changes—in skills, concepts, attitudes, etc.—and recorded his observations in permanent form. On the basis of the data so obtained the instructor was able to recommend the girl for an important college scholarship competition. (Incidentally the girl is now preparing for a career in plant research.)

Sample 4. *Carry-over to the community.* A class had been studying the problem of insects in relation to the transmission of disease. Some pupils observed a little later that there were a great many flies about the school kitchen and lunchroom. A committee from the class went to the principal and volunteered to locate the source of the flies. The committee found the source in a manure pile outside a barn near by. They suggested to the owner that he clean up the place. Upon his failure to do anything, they went to the local health department, and the manure pile was removed. In the meantime, other members of the class had voluntarily painted screens with a solution of D.D.T. and remained after school each night during the spring to spray the kitchen.

Needless to say, various parts of the situation as described provided the instructor with many instances of "significant behavior" upon which to base evaluations.

Sample 5. *Carry-over within the school.* A school was in the throes of an epidemic of colds. The school doctor suggested that the humidity of the classrooms was inadequate for good health. A number of boys in a general-science class overheard his remark and undertook to find the facts. They measured the humidity of all classrooms several times a day and recorded their findings. At the close of a month's study they summarized their data and presented their conclusions to the school doctor. He in turn gave the data to the school authorities, who took steps to improve conditions respecting humidity in all classrooms.

QUESTIONS AND EXERCISES

1. Discuss the relationship of evaluation to instructional goals in science instruction.
2. Discuss the advantages and disadvantages of paper and pencil devices for purposes of evaluation.
3. What changes are discernable in the emphasis on the evaluation of mastery of content over the past decade?
4. Discuss the advantages of frequent testing over end-of-semester or end-of-year testing.
5. Make up several objective test items that might be used for testing each of the following:
    (a) The functional understanding of a science principle.
    (b) The functional understanding of a science concept.
    (c) The mastery of a series of important science facts.
6. Make out what you would regard as a series of high quality essay questions in some area of science instruction. Present these to the class for criticism.
7. Make out an evaluating device to test the understanding of a demonstration selected from some area of high school science.
8. Select an experimental exercise from some area of high school science. State the outcomes you might reasonably expect to achieve from the experiment. Devise a test to show the extent to which each of the outcomes was realized.
9. Write an anecdotal record on some aspect of pupil behavior that might be observed in a high school science class.
10. Make out a sample laboratory report form for some experiment in high school science that would enable a teacher to more readily appraise the outcome of laboratory instruction.
11. What are the principles upon which the ability to interpret data depend?

12. Discuss the ten types of responses found by Horton in tests on the interpretation of data.
13. Make out a series of test items that might be used to test the ability to interpret data:
    (1) In a general science experiment.
    (2) In a biology experiment.
    (3) In a physics experiment.
    (4) In a chemistry experiment.
14. Make out a series of test items that might be used to evaluate the ability to apply principles in the same areas as noted in Exercise 13.
15. Devise a series of test items to test the ability to formulate hypotheses.

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Chapter 10

EXTRACURRICULAR ACTIVITIES IN SCIENCE

Science Clubs

During the past decade we have witnessed a rapidly growing interest and desire on the part of school administrators and supervisors to utilize extracurricular activities as a means of stimulating pupil participation and initiative in learning. The advantages of clubs over usual classroom procedures have been clearly stated by McKown[1] as follows:

Fig. 1 A science club at work.

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[1] McKown, H. C., *School Clubs,* Macmillan Co., New York, 1929.

The Club offers the pupil an opportunity for specialization which he does not have in the classroom. In the classroom his work is formal, in the club it is informal; in the classroom he is told what to do, in the club he chooses; in the classroom his method of dealing with a topic is clearly outlined by teacher imposed restrictions, in the club program the method is of his own devising; in a classroom he tries to please the teacher, in the club he works for his own and his club's interests and for the joy of doing this work; in the classroom he conforms to a system, in the club he suits his own convenience. In short, the club represents freedom and expression where the classroom represents conformity and repression.

Types and interests of science clubs. In a general way, science clubs may be divided into two groups: (1) the specialized interest club, such as the Radio Club, Camera Club, Aviation Club, Agriculture Club, Nature Club, etc.; (2) the general type club as the General Science Club, Biology Club, Chemistry Club, and Physics Club. Experience has shown that the specialized interest club is very frequently a short-lived club. This is particularly true in smaller schools. Webb[2] has reported on interests of science clubs from data gathered from nearly two hundred science clubs scattered over the United States.

These data are shown in Table 1. The middle column shows the interests of all the clubs, the right-hand column the interests of small clubs, and the left-hand column the interests of large clubs.

This investigation further revealed that the size of the clubs ranged from seven members to two hundred-forty members; the average being twenty-nine members. Meetings ranged from once a week to once a month with about half the clubs holding their meeting each alternate week. The clubs were about evenly divided as to the time meetings were held; fifty per cent holding their meetings during school hours and fifty per cent holding their meetings after school hours.

Organization of a club. The best results seem to be obtained in club work when the group is formally organized. This requires the adoption of a constitution. Meister, an authority on science

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[2] Webb, H. A., "Some First-Hand Information concerning Science Clubs," *School Science and Mathematics,* XXIX: 273–76, 1929.

TABLE 1

TYPES OF SCIENCE CLUBS

Large Clubs	No.	All Clubs	No.	Small Clubs	No.
Chemistry	17	General science	44	General science	30
General science	14	Chemistry	43	Chemistry	26
Physics	11	Physics	34	Physics	23
Biology	9	Biology	27	Biology	18
Radio	5	Radio	11	Nature	6
Nature	4	Nature	10	Radio	9
Experiments	2	Miscellaneous		Astronomy	4
Geography	2			Photography	4
Photography	2			Experiments	3
Agriculture	1			Aviation	3
Botany	1			Birds	2
Collections	1			Botany	2
Health	1			Current science	2
				Meteorology	2
				Engineering	1
				Field trips	1
				Geology	1
				Physiology	1
				Zoology	1

club work, suggests the following questions to be answered during the framing of the constitution:

(1) What shall be the aim and purpose of our Science Club?
(2) What shall be its name?
(3) Membership:
    (a) Who can become a member?
    (b) What must a boy or girl do to become a member?
(4) Meetings:
    (a) When shall they be held?
    (b) Where?
    (c) How often?
    (d) Who shall call for special meetings?
(5) Money:
    (a) Shall we pay dues?
    (b) How much?
    (c) Can we levy taxes?
    (d) How? How much?
    (e) For what shall the money be used?

(6) Expelling members:
  (a) For what reason or reasons?
(7) The business program:
  (a) How long shall it be?
  (b) What shall be the procedure?
(8) The science program:
  (a) How many different activities shall the club have?
  (b) Who shall decide upon and arrange these programs?
(9) Officers:
  (a) When shall elections take place?
  (b) How often?
  (c) What officers shall we have?
  (d) What shall be the duties of each officer?
  (e) How can an officer be impeached?
  (f) How can an officer resign?
  (g) Shall officers filling positions left vacant be appointed or elected? And how?
(10) Any other regulations you think it important to put into the constitution.

Most science clubs find it necessary to have the following officers: President, Vice President, Secretary, Treasurer, Sergeant-at-Arms, and Librarian. At the first meeting a set of temporary officers is elected. A committee to formulate a constitution is appointed. At the next meeting the constitution is discussed, revised if necessary, and finally adopted by a majority vote. A permanent set of officers is then elected as specified in the constitution.

Types of programs. The challenge of maintaining interest and enthusiasm in a science club can be met in large part by having interesting and varied programs.

The adviser or sponsor of a club should keep in mind, however, that the club is organized for the pupils. They should plan and execute the programs. Immature pupils do need guidance, however, and the adviser should see to it that planning for programs is not left to the last minute. The following activities have been found worthwhile in science club work and are offered as suggestions:

(1) Visual programs in which lantern slides, motion pictures, microprojector, or some other concrete visual aids are employed.

(2) School journeys. Visits to such places as a power plant, a mill, telephone exchange, weather bureau, zoological and botanical gardens, greenhouse, city water supply, filtration plant, modern dairy, and museums are always interesting and help to create interest in science.
(3) Work periods. Some club meetings should be set aside for the members to engage in individual work such as doing experiments, preparing demonstrations, or making posters and exhibits. In some science clubs every other meeting is made a work period.
(4) Current events. Some clubs devote one meeting a month to reports and discussions of new developments in science as reported in recent scientific magazines and newspapers.
(5) Science spelling match. This is an old-fashioned spelling bee in which only science words are used.
(6) Special speaker program. Science clubs enjoy hearing occasionally some expert or specialist such as a doctor, an engineer, a forester, or a bee-keeper.
(7) Science almanac. This program usually consists of reports on famous scientists born in a particular month.
(8) Science question-box.
(9) Science debates.
(10) Science plays.

Materials that will be useful in forming a science club. Every teacher or sponser who is planning to start a science club in his school should secure the Sponser's Handbook published by Science Clubs of America, Science Service, Washington, D. C. This manual is a rich source of information on how to start a club and how to conduct it. There are suggestions for over a thousand club projects. As soon as a club is formed it should be registered with the above-named group, as the club will then become eligible for a number of useful services supplied by the organization.

Another useful booklet entitled "How To Organize A Science Club" was published by The American Institute of the City of New York, 60 East 42nd St., New York City. This pamphlet contains many very useful suggestions on organizing and conducting the activities of a science club.

Still another booklet that will be found useful to both sponsers and pupils alike is entitled "Student's Handbook of Science." This is published by the Frederick Ungar Publishing Co., New York City.

Assembly Programs

In many schools assembly programs are planned from time to time to provide opportunities for the presentation of extra-curricular work. Science departments and science clubs should participate in such activities, because they often have unique, interesting, and educationally worthwhile materials to contribute to the programs.

The plan for developing a school assembly program in science should be made with the interests of the audience definitely in mind. Consideration should be given to the educational worthwhileness of materials as well as to their adaptability for the auditorium. If the age range of the audience is from the seventh grade to the twelfth grade, for example, some materials of interest to the younger pupils should be included as well as materials that will be of interest to the older pupils.

The pupils who are to participate in the assembly program should plan their presentation with great care. They should be alert to see that the vocabulary used is at the level of understanding of the audience and that each presentation will hold the interest of the group. Where a demonstration is to be a part of the presentation, it should be performed with equipment that may be seen clearly from all parts of the auditorium. If experiments must be performed with small equipment such as test tubes, some plan of projecting the demonstration on a screen with a stereoptican lantern may be used. When charts are to be used they should be made large enough to be clearly seen from the back of the room. Experience has shown that large white wrapping paper may be used to advantage in making such enlarged charts.

Many types of programs may be used for assemblies. The resourceful teacher will have no difficulty in finding interesting and worth-while materials for assembly programs both from the classroom and the activities of the science club. In some cases a program may be planned around a single activity, while in others a series of science activities may be utilized. Where projection equipment is available, the science department or the science club may sponser a motion picture program with a film selected from the lists in Part III of this book. There are many free and low-rental films available that make excellent material for a science assembly program.

Some suggested topics for science assembly programs:

(1) The mysteries of liquid air.
(2) Atomic energy.
(3) A day's work in the science club.
(4) The school nature trail.
(5) How our water is purified.
(6) Birds of this locality.
(7) How I made a telescope.
(8) Science hobbies in the school.
(9) Electronics and radio.
(10) How the health of our community is protected.
(11) Scientific information for the consumer.
(12) Science and safety.
(13) Science and magic.
(14) Conservation in our locality.
(15) The living things in a drop of water (microprojection).
(16) Observing the weather.
(17) Attracting birds with a feeding station.
(18) A trip to a local industry.
(19) Great men of science.
(20) Growing plants without soil.
(21) Our science museum.
(22) Experiments with light.
(23) How the elements are classified.
(24) Vocational opportunities in science.
(25) My home laboratory.

The Science Fair

The science fair is an excellent device for acquainting the parents of the local school, as well as other people in the community, with the science work that is being done. In many communities over the country science fairs have become established as annual events. In these larger community projects awards are given for the best exhibits.

Perhaps the best time of year to plan for a science fair is in the spring. This provides the major part of the school year for pupils to plan and develop the projects they will exhibit. At the same time, it gives the committees planning the fair opportunity to make adequate preparations and plan whatever publicity they may wish to provide.

Experience has indicated that the fair may be housed either in the school gymnasium or the corridors and the classrooms. In many instances the classrooms are to be preferred over the gymnasium, especially if the science fair is to demonstrate the work of the classroom as well as that of the science club. Many of the experiments and demonstrations used in classroom experiences in science may require the use of running water or of gas. For such exhibits the science classroom is almost indispensable.

Careful planning by several committees is essential to the success of a science fair. One committee must plan the location of each exhibit. For such planning this committee should have from each entry a slip stating the name of the exhibit, material needed such as water, gas, electricity, and the approximate amount of table space the exhibit will occupy. The entry slip should also state whether the exhibit will require wall space for charts. If the science fair is to demonstrate the science work of the school, it will be well to place the exhibits of each grade together. It may even be possible to place these exhibits in such a way as to form a natural development of the science course for a given grade.

Another committee may be formed to make the identification signs for each exhibit. These should be of uniform size and lettering. Each sign should carry the title of the exhibit, the name of the exhibition, the grade, and perhaps an identification number which appears on the program given to visitors. A set of letter stencils make the preparation of these signs much easier.

Setting up the exhibit is a very real and time consuming undertaking and should be planned with great care. The adults in charge should be alert to possibilities of fire, and if this is a danger it may be well to have one teacher always present in the room while the demonstrations are going on. The pupils should be expected to arrange the exhibits in an orderly and, as far as possible, artistic manner. All charts should be inspected by a committee and passed upon as neat enough to be put up.

Some of the exhibits of the fair will of necessity have to be planned as special exhibits to be shown at certain specified times. Such a demonstration as liquid air might be planned to have showings at intervals of one hour. For exhibits that are to have continuous showing, it has proved wise to have two pupils prepared to give each demonstration. This makes it possible to have one pupil at the demonstration all the time.

The question of awards is, in the opinion of the authors, quite debatable. This seems to be in line with the most recent thinking on the whole subject of singling out individuals for special citation. In a science fair there are so many intangible factors that could not possibly be taken into account in rating exhibits that it is probably better to dispense with any judging. The pupils, rather, should be encouraged to work for excellence in the exhibit as a whole rather than for the awards.

Help on planning a science fair may be secured from the "Sponser's Handbook" published by Science Clubs of America.[3]

The Science Museum

Planning and developing a science museum is a project that may well enlist the interest and the efforts of all science classes in the school as well as the science club. A science fair may be the beginnings of a science museum for the school. There will, no doubt, be some exhibits in the science fair that should be saved for future instructional purposes. Perhaps some of the charts can be used again and again for instruction. These can be used as a nucleus for the science museum.

The beginnings of a museum need not be pretentious. Indeed, it is probably a much wiser procedure to begin with a shelf or table in the science room. Such space can be used for exhibits. If the materials outgrow this space perhaps they can be stored away in boxes for a year or so until there are a sufficient number of exhibits to convince the administrative authorities of the school that more space is essential for display. Some schools have found room in the basement to build cases, while in others display cases have been put in the corridors.

[3] Science Clubs of America, Science Service, Washington, D. C.

One important point in building a successful science museum is to avoid making it a graveyard for curios sent in by parents of pupils. This is not said to discourage gifts of worth-while specimens and collections that some family may wish to give to the museum. Each new addition to the museum, whether it be a fossil brought in by a pupil, or a collection of butterflies presented by some collector, should be judged by a museum committee as to its educational value. Each new acquisition for the museum should be carefully labelled. The label should tell the nature of the specimen, the donor, and if possible, where it came from. The arranging, labelling, and caring for museum materials may well be put in the hands of student committees. If possible, all exhibits should be kept in locked cabinets.

A little time spent in canvassing the community may reveal some very educational materials that can be acquired on a loan basis or perhaps given to the school when the community learns that a place to house exhibits has been created.

Pupil projects of excellence may be added to the museum collection. The museum should include materials from the field of physical science as well as from nature and biological science. Rocks, minerals, and fossils will naturally find their way to the museum shelves, but there should also be exhibits of other materials from physical science. For example, an exhibit of early types of lighting devices can make a very worth-while and educational display.

Small mineral and fossil samples that might be misplaced or lost can be preserved by imbedding them in plaster of Paris. A mold for such plaster of Paris bases may be made from small tin can covers. Pupils who are skillful in the wood-working shop may be encouraged to make small wood blocks with a sloping face upon which mineral samples may be placed. The identification card may be fastened to the sloping face of the block.

A filing cabinet placed in the museum may be used to hold papers written by pupils about their projects as well as pamphlets collected on various subjects of scientific interest. All materials in the museum should be carefully cataloged as they are added.

This may be done either in a notebook or on library cards. The card system of cataloging has many advantages.

The Science Talent Search

For a number of years now the Science Clubs of America Inc. has conducted an annual science talent search. This is a competition between seniors in high school for the Westinghouse Science Scholarships. These scholarships range in value from $2400 to $100 and total $11,000 annually. The scholarships are awarded to 40 winners selected from all parts of the country who are invited to the Science Talent Institute conducted for five days each spring in Washington, D. C. The expenses of the winners are paid by the Institute. In addition, 260 boys and girls are selected for honorable mention.

Elimination for the scholarships is made on the basis of a test in science and a scientific project which is reported by the boy or girl. For further information on the Science Talent Search the reader is referred to Science Clubs of America, Science Service, Washington, D. C.

The Nature Trail

Many schools over the country are located near enough to parks and other wooded areas to lay out a nature trail. Such a trail is a very useful and educational device for nature study and for special study by classes in general science and biology. Some schools have used the nature trail idea as a class or a science club project.

The path of the trail is decided upon and then it is clearly marked out with suitable permanent signs. Interesting nature materials along the trail are finally marked. Identification tags are placed on trees and shrubs as permanent markings. Each season new markings are placed along the trail to indicate things of new interest such as new wildflowers, birds' nests, etc.

QUESTIONS AND EXERCISES

1. Make a plan for organizing a science club in a school where you might teach.

2. Discuss the values of the science club as an educational device.
3. Work out plans for a science assembly program on one of the topics listed in this Chapter.
4. Make plans for a science fair on the elementary school level.
5. Make plans for a science fair on the high school level.
6. Discuss the pro's and con's of awards for exhibits at science fairs.
7. Draw up plans for laying out a nature trail on the campus of your school or in a nearby park or woodlot.
8. Write out a discussion of your views on the Science Talent Search conducted by Science Clubs of America.

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SECTION II

Equipment for Teaching Science

Chapter 11

THE SCIENCE CLASSROOM AND LABORATORY

The Problems of Space for Teaching Science

The teaching of science has the peculiar problem of adequate rooms shared only by a few other subjects in the school curriculum. Because a considerable part of the time spent in learning science is devoted to experimental work of one sort or another, the problem of providing adequate laboratory facilities must be faced and dealt with. Even within the science area there are varied problems of space since a different type of room is needed for the teaching of elementary science than is needed for any of the specialized sciences taught on the senior high school level.

There can be little doubt but that in the past space for science teaching has been poorly planned. Parker, in a comprehensive study of eight cosmopolitan high schools in New York City, found chemistry laboratories with a total capacity of 4,350 students but with a total enrollment of 1,787 students or 41 per cent of the capacity.

Physics laboratories in the eight high schools had a capacity of 3,010 pupils and an enrollment of 863, or 29 per cent of their capacity. In other words, the chemistry laboratories were idle 59 per cent of the time; physics laboratories, 71 per cent of the time; and biological laboratories, 44 per cent of the time. The waste in smaller high schools is even more pronounced. In a large majority of public high schools there is but one science teacher and therefore there can be little need for more than one laboratory in the average school.

In view of the great economic loss due to having separate classrooms and laboratories for science it seems advisable to have science rooms equipped with a type of furniture which will provide for all types of classroom activities, demonstration work, and laboratory work. Such a combination room is a much more flexible place to carry on activities of a problem solving nature because it enables the class work to be shifted at any time from developmental to experimental, and back. Thus experiments may be performed at a time in the solution of a problem when they are most effective and without moving the class to another room.

Planning the Science Room

It is highly desirable that science teachers become familiar with the best practices in the designing and equipping of science rooms. This is important because there is an increasing tendency for school architects to seek advice from science teachers regarding their needs in the efficient use of space. In this section certain general ideas will be presented, to be followed later in the chapter by a discussion of special problems of science rooms for different levels of instruction.

The *Thirty-First Yearbook* of the National Society for the Study of Education[1] set forth certain basic principles regarding science rooms which may serve as guides in effective planning. A selected group of these are given below:

(1) A science room is a place where the pupil may receive educative experiences which add meanings to, and give better understandings of, those generalizations in science that contribute to enrichment of life.
(2) Science room experiences are justified by, and take their origin from, the science curriculum, courses of study, and learning experiences to be expected of pupils.
(3) A science room is also a place where the experience of problem-solving is possible.
(4) The plan and design of a science room must provide elements of flexibility.
(5) The design of both class rooms and laboratories should provide facilities for effective teacher demonstrations.
(6) Science rooms should provide facilities for individual laboratory work.

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[1] *Thirty-First Yearbook,* A Program for Teaching Science, *op. cit.*

(7) Science rooms should provide certain facilities for objectification by means other than the use of concrete materials (blackboard, bulletin board, display fixtures, visual aids, etc.)

(8) The planning of science rooms and their equipment should be a cooperative project, in which the architect, the engineer, the educational supervisor, and the science teacher each play a proper part.

Size of science room. There is at present no objectively determined size for science rooms. Since the number of pupils in science classes vary widely from school to school and from year to year, it is possible to give only a broad general statement on this problem. However, it may be said that classroom and laboratory facilities should be planned to comfortably and efficiently take care of the optimum class size for instruction. In justice to both pupil and teacher this should not exceed twenty five students.

General type of laboratory furniture. In any room that is specifically planned for science activities there should be an instructor's demonstration table. This table should be from 8 to 12 feet in length, and centered in the front of the room. It should be equipped with sink, hot and cold running water, gas, and electrical outlets. The demonstration table top should be of an acid and alkali resistant material. The back of the table should be fitted with drawers and cupboard space for storing materials commonly used in demonstration work. The front and ends of the table may have built-in key cupboards or spaces in which to file student notebooks and papers.

In some plans the entire science room is equipped with one form or another of a combination laboratory-recitation desk. In such cases the pupil sits at the laboratory desk and by moving the chair may stand while doing experiments. In the use of these combination desks there are some advantages, as well as some disadvantages. These will be discussed at a later point in the chapter.

In the purchase of furniture for a science room, experience has shown that it is always a wise policy to purchase the best equipment. Such furniture is given very hard usage and unless good quality materials are purchased at the outset the cost of upkeep on inferior equipment may soon be greater than the original cost of the best furniture.

There are a number of reputable manufacturers of laboratory furniture that maintain facilities for building equipment for specific rooms. In the long run equipment supplied by such companies will be found much more serviceable than homemade materials. Plumbing fixtures in a laboratory are very important. They should be made of brass or copper heavily chrome-plated and the sinks should be made of soap stone to be acid resistant. Experience has indicated that a type of faucet equipped with a flexible joint at the base, to permit the faucet being bent down into the sink when not in use, is the most serviceable. All laboratory tables should be equipped with gas and electrical outlets whenever these utilities are available. Plenty of drawer and cupboard space in the bottom part of laboratory desks is essential for the storage of equipment. All drawers and cupboards should be equipped with keys and locks.

Storage cabinets. In planning the science room it is very important to plan adequate storage space for the variety of apparatus, objects, specimens, and models used in teaching. There should be a number of dust proof cupboards for physical, biological, and chemical apparatus. Such cabinets may also be used for dry chemicals. It is important that acids and other liquid chemicals be stored in a cabinet treated on the inside with acid-proof paint. Such chemicals should be stored in a place that will keep the fumes well away from metal apparatus which might be injured by them. Cabinets should be equipped with rolling doors mounted on suitable tracks. All cabinets should have individual locks. A chest of small drawers makes a convenient place to store many of the smaller pieces of equipment.

Such a cabinet should contain from fifty to seventy-five drawers each about 9 inches by 6 inches on the face side and 10 to 12 inches in length. A cabinet for the storage of charts, maps, and flat pictures is essential in the science room.

One of the best motivating devices that a teacher can have is a display place for pupils' work. This may be just a shelf but experience has shown that a cabinet with glass doors is to be preferred.

Bulletin board and blackboard. No science room can be regarded as adequate without some form of bulletin board where current science materials from the newspaper and magazines may be placed. A bulletin board can be made by members of the class from a piece of wallboard. Some teachers prefer to cover the board with green denim or burlap and place a frame around it to lend attractiveness.

Ample blackboard space should be provided both in back of the demonstration table and along one wall. The newer types of blackboard are much easier on the pupils' eyes than the older slate-type boards.

Window benches. Many modern laboratories are equipped with work spaces along the windows. These benches usually have the regular acid-proof tops and are of window-ledge height. Many things such as plants and aquaria which need light may be placed on them. The under portion of these benches may be equipped with storage cupboards for equipment.

Stockroom and darkroom. Wherever possible it is desirable to have a combination stockroom and preparation room adjoining the science room. This room may be used also as a dark room for certain experiments in the topic of light as well as for photographic work. The room should have hot and cold running water, gas, and electricity. The wall space should be used for storage cabinets and work space for the teacher to make up chemical solutions and prepare demonstrations. A workbench equipped with a good set of tools and a vise is also essential.

Fumehood. If the science room is to be used for chemistry it is essential that either the individual laboratory desks be equipped with fumehoods or that a suitable wall-type fumehood be installed. Such fumehoods need to be equipped with a blower system to remove poisonous fumes from the hood.

Book cabinets. If the school maintains departmental libraries it is important to have a cabinet for storing the books. In any event it is desirable to have several sets of textbooks in the science room as well as books of general scientific reference, such as handbooks and identification keys. Many teachers like to collect educational materials from industrial concerns and keep them for instructional purposes from year to year. These may also be stored in the book cabinet.

Filing cabinet. Much excellent teaching material accumulates from year to year from bulletin board displays of current articles, such as those obtained from magazines and newspapers. Many teachers find that an ordinary filing cabinet is an efficient way of indexing and storing such material for future use.

Planning Workrooms for Science in the Elementary School

With the increasing emphasis on science in the elementary school, more attention needs to be directed toward the provision of adequate facilities. This is of particular importance where new buildings are being planned and school administrators and architects may be seeking guidance on plans from science teachers.

There is some tendency on the part of school authorities to regard elementary science as just another course needing only a textbook for adequate instruction; they therefore give little or no attention to the specialized types of learning situations that may arise. And again, some administrators believe that the elementary science teacher should be able to borrow materials needed from the science department of the junior or senior high school in the system. These influences tend to retard effective teaching in elementary science.

The nature of the elementary school pupil demands that special consideration be given to his needs and interests as apart from any other science taught in the school curriculum. The facilities and the materials provided for more mature pupils are, for the most part, not adequate for the teaching of elementary school science. Craig,[2] one of the outstanding authorities in the field of elementary school science, has listed the following as purposes of the elementary science workroom:

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[2] Craig, Gerald S., "The Place of the Science Workroom in the Elementary School Program," *Science Education*, XIV: 582–589, May 1930.

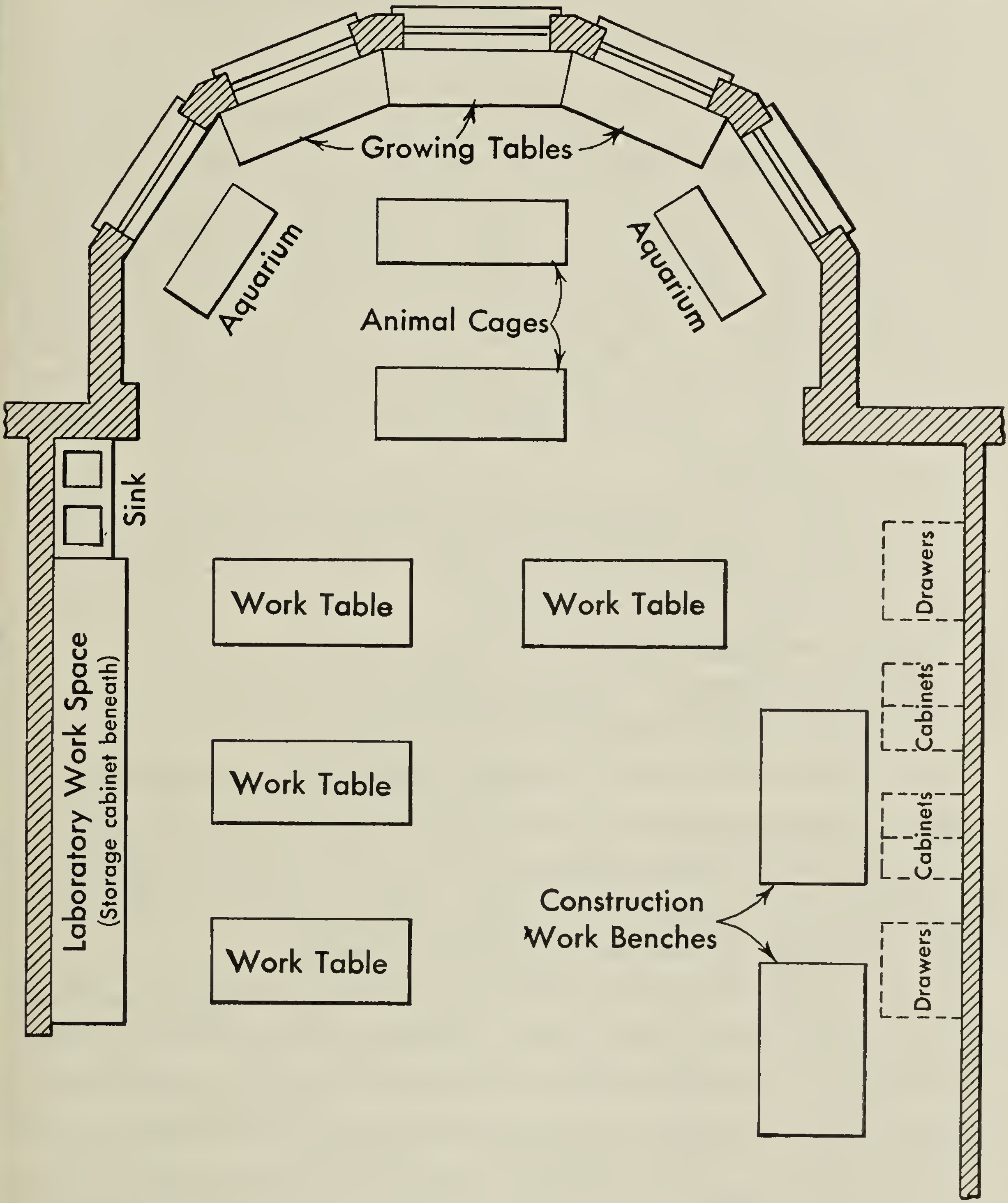
Growing Tables
Aquarium
Aquarium
Animal Cages
Sink
Work Table
Work Table
Work Table
Work Table
Laboratory Work Space
(Storage cabinet beneath)
Drawers
Cabinets
Cabinets
Drawers
Construction Work Benches

Fig. 2 Floor plan for an elementary science room.

(1) To provide an environment which will render a setting compatible with readiness for learning the elements set forth in the course of study.

(2) To demonstrate the elements of learning set forth in the course of study and make them acceptable to the learner.

(3) To provide for experiences which give exercise and drill for the elements of learning set forth in the course of study.

(4) To give opportunity for student participation in constructing, assembling, caring for, and amplifying the materials of instruction.
(5) To develop and maintain the individual and group interest and activities in science.

The workroom for elementary science should be planned to give a well-rounded experience in science. It is essential that pupils have rich experiences in every phase and aspect of science including plants, animals, air, light, machines, and others. Providing learning experiences in these areas of science demands specialized facilities. These facilities need to be carefully planned not only from the point of view of the specific needs of elementary school pupils but also with regard to the instruction that takes place in the classroom.

Craig[3] points out that the science workroom should be evaluated in terms of three types of instructional organization to be found in elementary science programs:

(1) Departmentalized organization of instruction.
(2) The single classroom teacher organization of instruction.
(3) Fusion or modified organization of instruction.

In the departmentalized plan the pupils go to a science room for their instruction, which is provided by a specialist. There may be one specialist to handle all the science, or there may be a specialist provided for the physical science aspects of the course while another specialist teaches the biological materials.

In the single classroom plan the regular elementary science teacher teaches the science along with the other subjects in the curriculum. In this plan the work may be taught in the regular classroom or the teacher may move the class to the science room if special equipment and facilities are needed for a particular lesson.

In the fused plan the classroom teacher and the science specialist are jointly responsible for the instruction in science. The specialist moves from room to room in the school as he is needed. If special facilities are needed the class may be moved to the science room.

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[3] Craig, *op. cit.*

The All-Science Combination Laboratory for the Small and Medium-Sized High School

Some of the major companies engaged in the manufacture of furniture for science rooms have made exhaustive studies of the most economical ways to meet the needs created by limited floor space and the placing of furniture. The results of these studies show clearly that the combination classroom and laboratory plan has many advantages over the older separate classroom and laboratory plan. In the small and medium-sized high school, where one or two teachers teach all the science, a single laboratory can be planned to adequately take care of all the sciences in a minimum of floor space. Two such floor plans are shown below. Each of these laboratories is designed for twenty-four students. In the plan shown in Fig. 3 six laboratory tables are arranged in front of the instructor's table. Each table has water connections and a sink at the center. Four pupils sit at each table. Two pupils at each table face the instructor's desk and two face in the opposite direction. When demonstration work is being conducted these latter two students face their chairs toward the front or sit at the ends of the laboratory tables.

In the plan shown in Fig. 4 twelve smaller laboratory tables are placed in front of the instructor's desk. With this plan all pupils face the front of the room. The adjacent preparation and storage rooms provide helpful facilities for the instructor. Either of these rooms may be used by classes other than science, thus making for maximum efficiency in the utilization of room facilities in a building. The per-pupil cost of the equipment shown in Fig. 4 is somewhat higher than that where the larger tables are used.

A combination general science and biology laboratory. In some schools, where a single science laboratory is not adequate to provide for the needs of all science classes, it has been possible to combine the facilities for general science and biology. With this type of plan it has been found that running water at the instructor's table in the front of the room and at a large utility sink in the rear of the room has proved adequate. The per-pupil cost of this installation is considerably reduced by the elimination of individual table plumbing. This room may also be used for other classes than science. Fig. 5 shows a floor plan of this type of room.

Combination chemistry and physics laboratories. In schools, where one combination laboratory is provided for general science and biology, it may be desirable also to have a combination room for classes in physics and chemistry. Figs. 6 and 7 show two plans for such a combination room. In Fig. 7 the Lincoln type science table is used, while in the other the six-student type table is used. In the Lincoln type laboratory desk each student has a separate wing providing a desk at the correct height when seated. This may be used for physics experiments or for writing. The central unit provides a standing height chemistry table with all service outlets conveniently located and a sink for each two pupils.

The six-student table plan shown in Fig. 6 is most efficient in its use of floor space and has a lower per-pupil installation cost. It has the disadvantage of not providing a center aisle.

Plans for Separate Laboratories for the Specialized Sciences

In larger high schools where the enrollment is sufficiently high to demand separate rooms for biology, physics, and chemistry, it has been found that the combination classroom and laboratory makes for the most efficient use of available floor space. Figs. 10 and 11 show layout plans for a physics laboratory. Figs. 12 and 13 show two plans for a biology laboratory and Fig. 16 shows a plan for a chemistry laboratory.

QUESTIONS AND EXERCISES

1. Draw to scale an ideal science room layout for your own school.
2. Draw up a suitable plan for converting an unused room in an elementary school building into a science room.
3. Draw up plans for a portable demonstration table on wheels that might be moved from one classroom to another.
4. Critically evaluate one of the floor plans given for general science in the light of some actual school situation with which you are familiar.
5. What type of science rooms and equipment would you recommend to a school architect designing a new high school building for a rural, consolidated school system with 500 pupils?

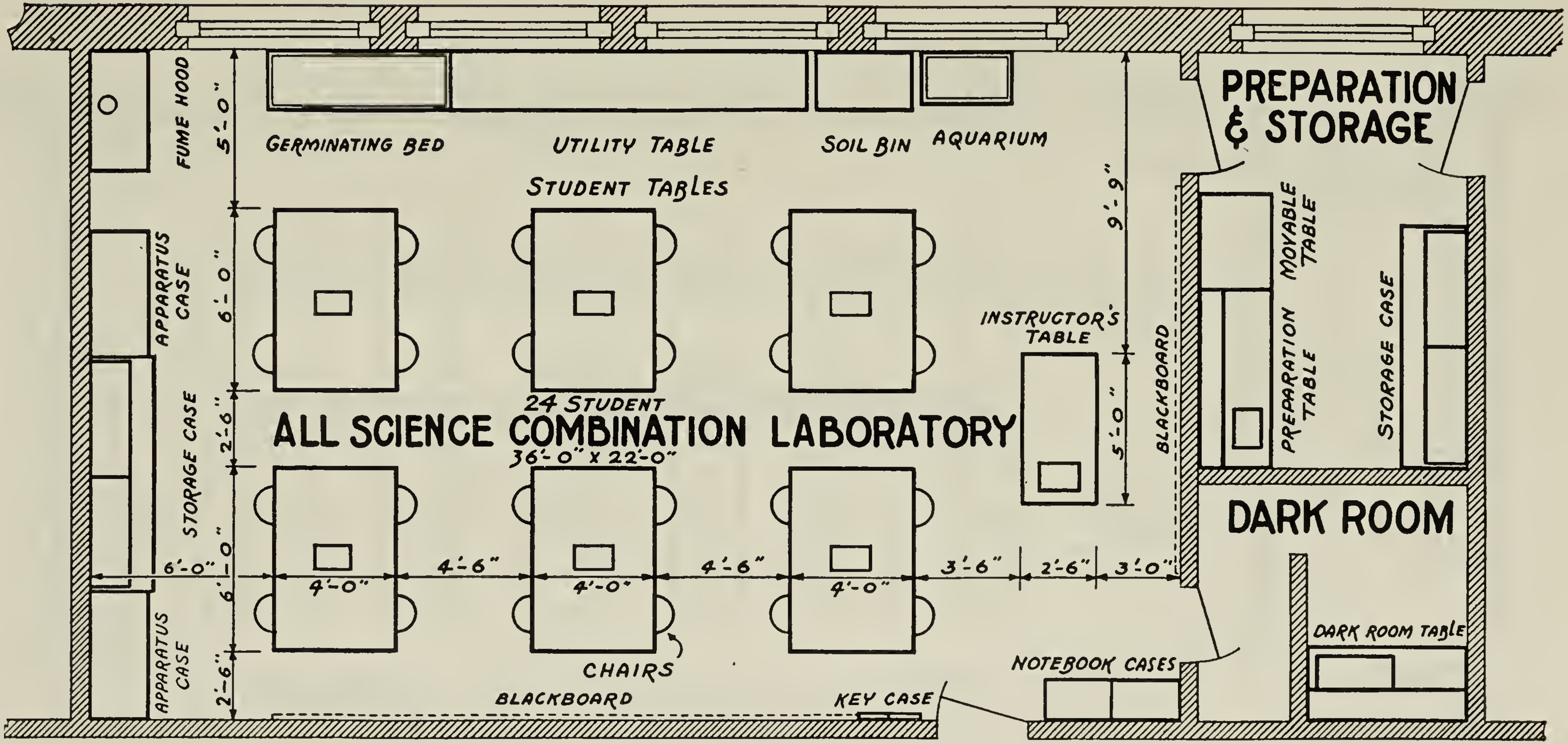
PREPARATION & STORAGE
FUME HOOD
5'-0"
GERMINATING BED
UTILITY TABLE
SOIL BIN
AQUARIUM
STUDENT TABLES
MOVABLE TABLE
PREPARATION TABLE
STORAGE CASE
9'-9"
APPARATUS CASE
6'-0"
INSTRUCTOR'S TABLE
BLACKBOARD
5'-0"
24 STUDENT
ALL SCIENCE COMBINATION LABORATORY
36'-0" X 22'-0"
STORAGE CASE
2'-6"
DARK ROOM
6'-0"
4'-0"
4'-6"
4'-0"
4'-6"
4'-0"
3'-6"
2'-6"
3'-0"
6'-0"
APPARATUS CASE
2'-6"
CHAIRS
DARK ROOM TABLE
NOTEBOOK CASES
BLACKBOARD
KEY CASE

Fig. 3 Floor plan for an all science combination laboratory.
(Courtesy Kewaunee Mfg. Co., Adrian, Mich.)

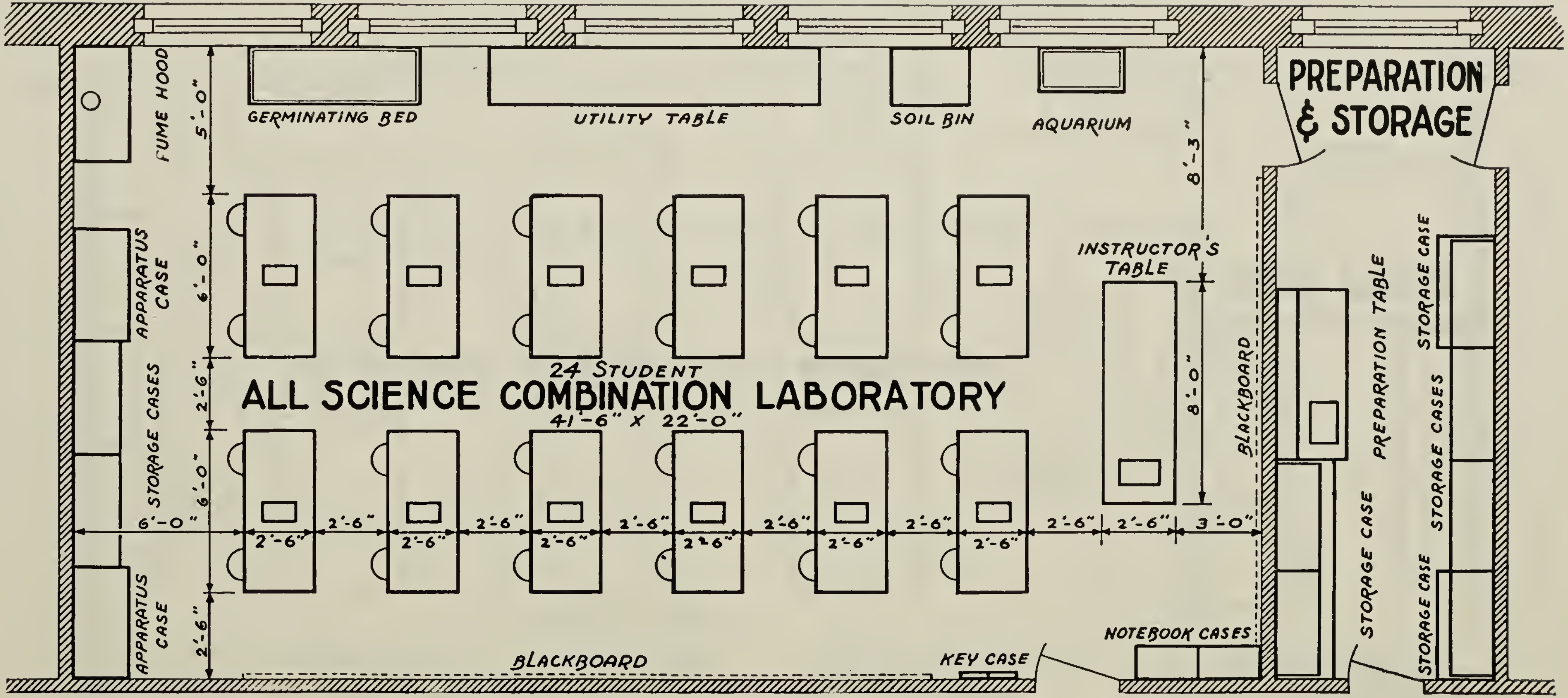
PREPARATION & STORAGE
FUME HOOD
GERMINATING BED
UTILITY TABLE
SOIL BIN
AQUARIUM
8'-3"
INSTRUCTOR'S TABLE
8'-0"
APPARATUS CASE
STORAGE CASES
APPARATUS CASE
5'-0"
6'-0"
2'-6"
6'-0"
2'-6"
24 STUDENT
ALL SCIENCE COMBINATION LABORATORY
41'-6" X 22'-0"
6'-0"
2'-6"
2'-6"
2'-6"
2'-6"
2'-6"
2'-6"
2'-6"
2'-6"
2'-6"
2'-6"
2'-6"
2'-6"
2'-6"
2'-6"
3'-0"
BLACKBOARD
PREPARATION TABLE
STORAGE CASE
STORAGE CASES
STORAGE CASE
STORAGE CASE
NOTEBOOK CASES
KEY CASE
BLACKBOARD

Fig. 4 Floor plan for an all science combination laboratory. (*Courtesy Kewaunee Mfg. Co., Adrian, Mich.*)

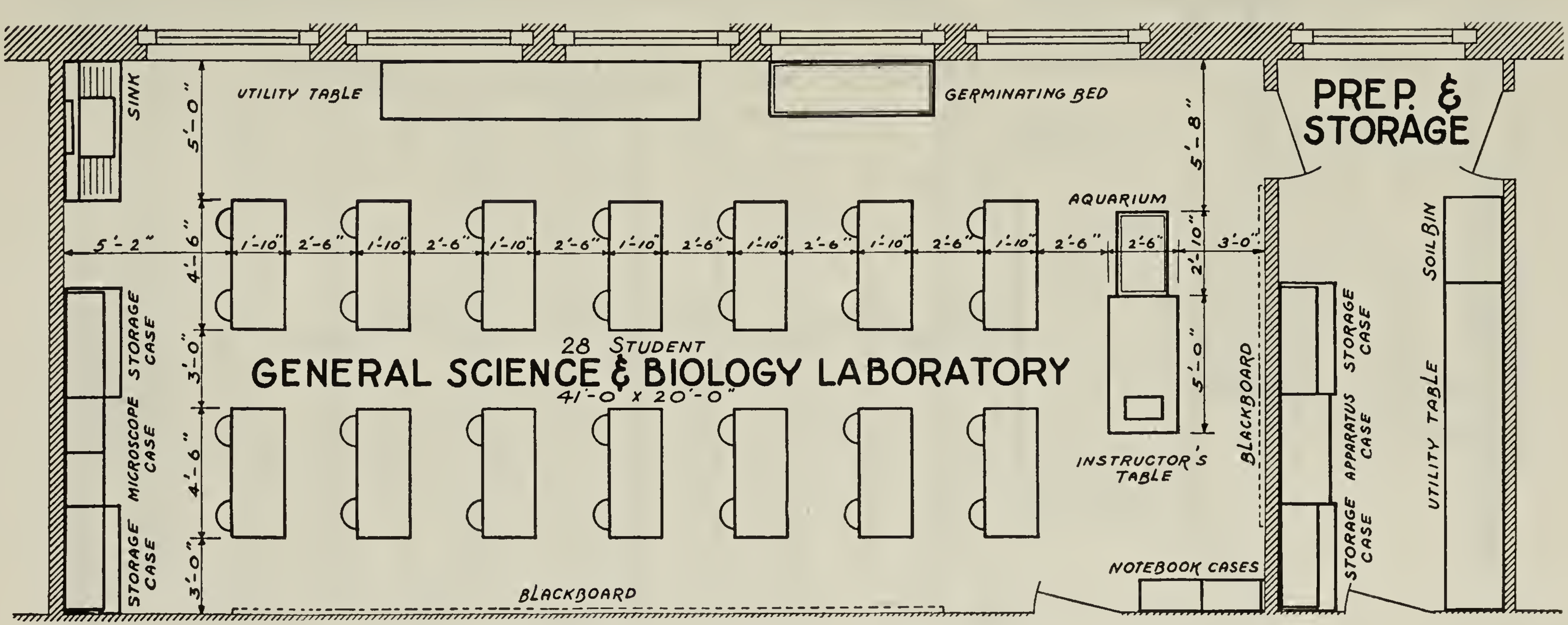
UTILITY TABLE
GERMINATING BED
PREP. & STORAGE
SINK
5'-0"
5'-8"
AQUARIUM
5'-2"
4'-6"
1'-10"
2'-6"
2'-6"
10"
2'-10"
3'-0"
SOIL BIN
STORAGE CASE
MICROSCOPE CASE
STORAGE CASE
3'-0"
4'-6"
3'-0"
28 STUDENT
GENERAL SCIENCE & BIOLOGY LABORATORY
41'-0" x 20'-0"
5'-0"
BLACKBOARD
STORAGE CASE
APPARATUS CASE
STORAGE CASE
UTILITY TABLE
INSTRUCTOR'S TABLE
NOTEBOOK CASES
BLACKBOARD

Fig. 5 Floor plan for a combination general science and biology laboratory. (*Courtesy Kewaunee Mfg. Co., Adrian, Mich.*)

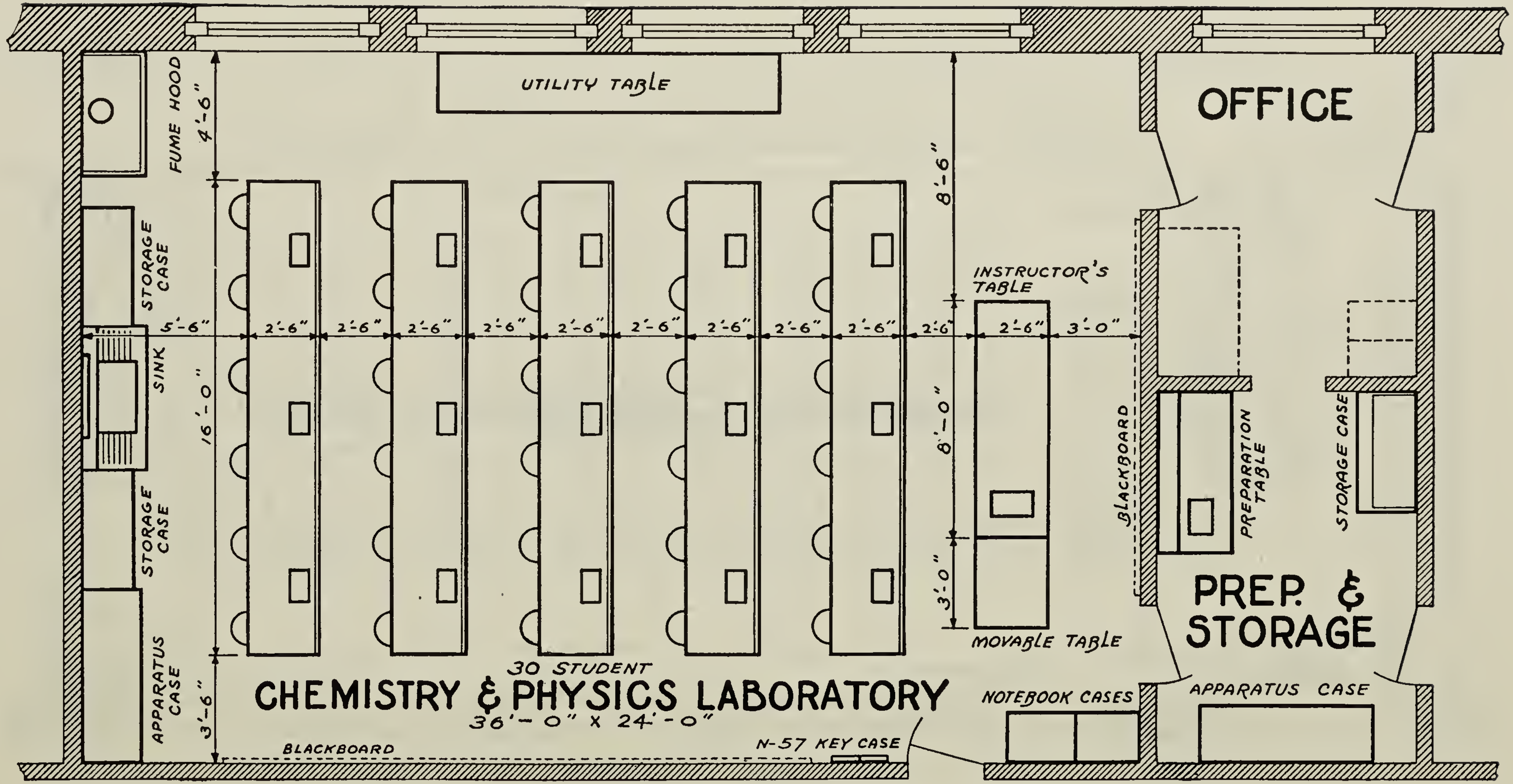
UTILITY TABLE
OFFICE
FUME HOOD
4'-6"
8'-6"
STORAGE CASE
INSTRUCTOR'S TABLE
5'-6"
2'-6"
2'-6"
2'-6"
2'-6"
2'-6"
2'-6"
2'-6"
2'-6"
2'-6"
2'-6"
2'-6"
3'-0"
SINK
16'-0"
8'-0"
BLACKBOARD
PREPARATION TABLE
STORAGE CASE
STORAGE CASE
3'-0"
PREP. & STORAGE
MOVABLE TABLE
30 STUDENT
CHEMISTRY & PHYSICS LABORATORY
36'-0" x 24'-0"
APPARATUS CASE
3'-6"
NOTEBOOK CASES
APPARATUS CASE
BLACKBOARD
N-57 KEY CASE

Fig. 6 Floor plan for a combination chemistry and physics laboratory. (*Courtesy Kewaunee Mfg. Co., Adrian, Mich.*)

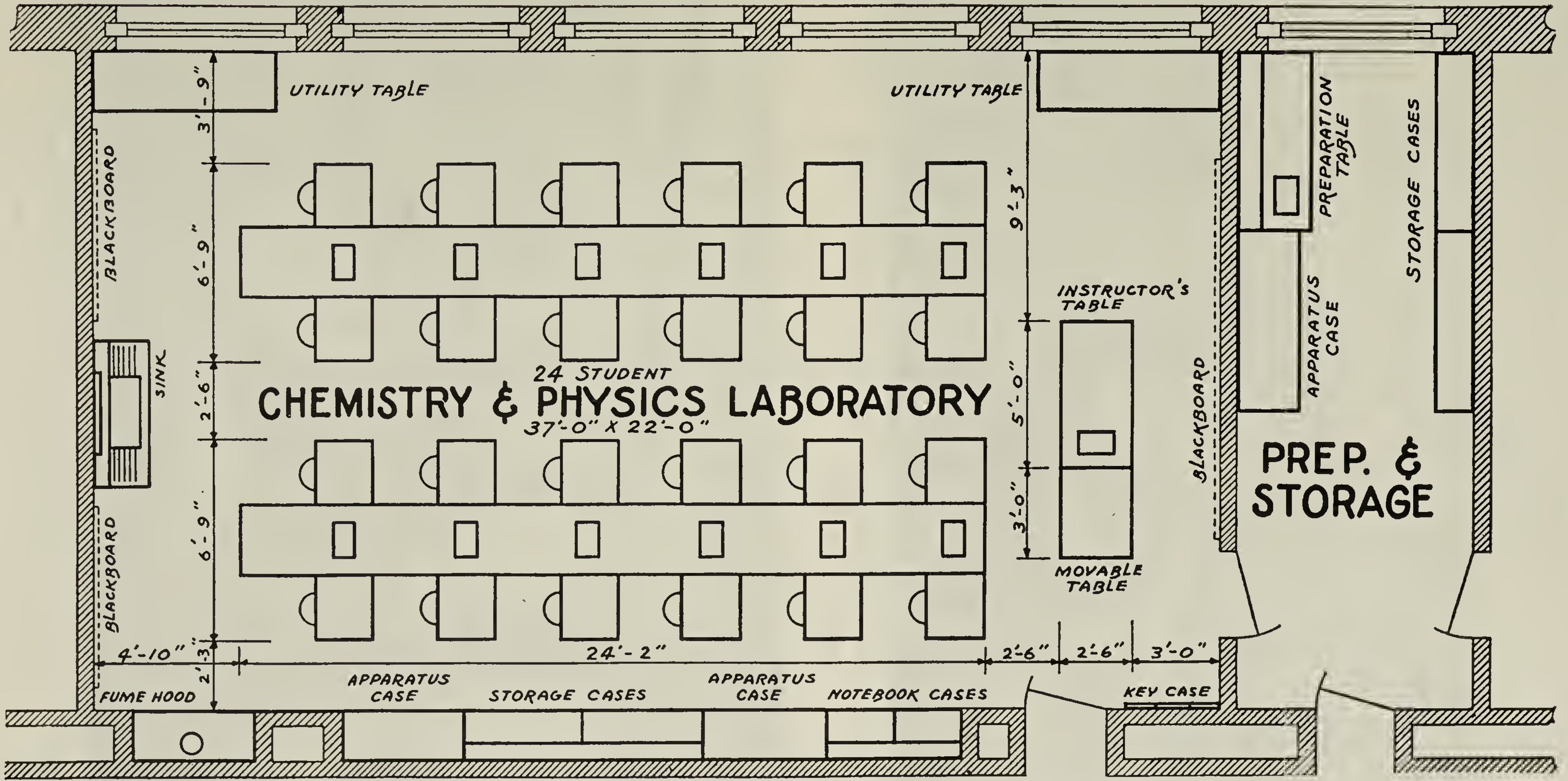
UTILITY TABLE
UTILITY TABLE
3'-9"
6'-9"
2'-6"
6'-9"
2'-3"
9'-3"
5'-0"
3'-0"
BLACKBOARD
SINK
BLACKBOARD
24 STUDENT
CHEMISTRY & PHYSICS LABORATORY
37'-0" X 22'-0"
INSTRUCTOR'S TABLE
MOVABLE TABLE
BLACKBOARD
PREPARATION TABLE
APPARATUS CASE
STORAGE CASES
PREP. & STORAGE
4'-10"
24'-2"
2'-6"
2'-6"
3'-0"
FUME HOOD
APPARATUS CASE
STORAGE CASES
APPARATUS CASE
NOTEBOOK CASES
KEY CASE

Fig. 7 Floor plan for a combination chemistry and physics laboratory. (*Courtesy Kewaunee Mfg. Co., Adrian, Mich.*)

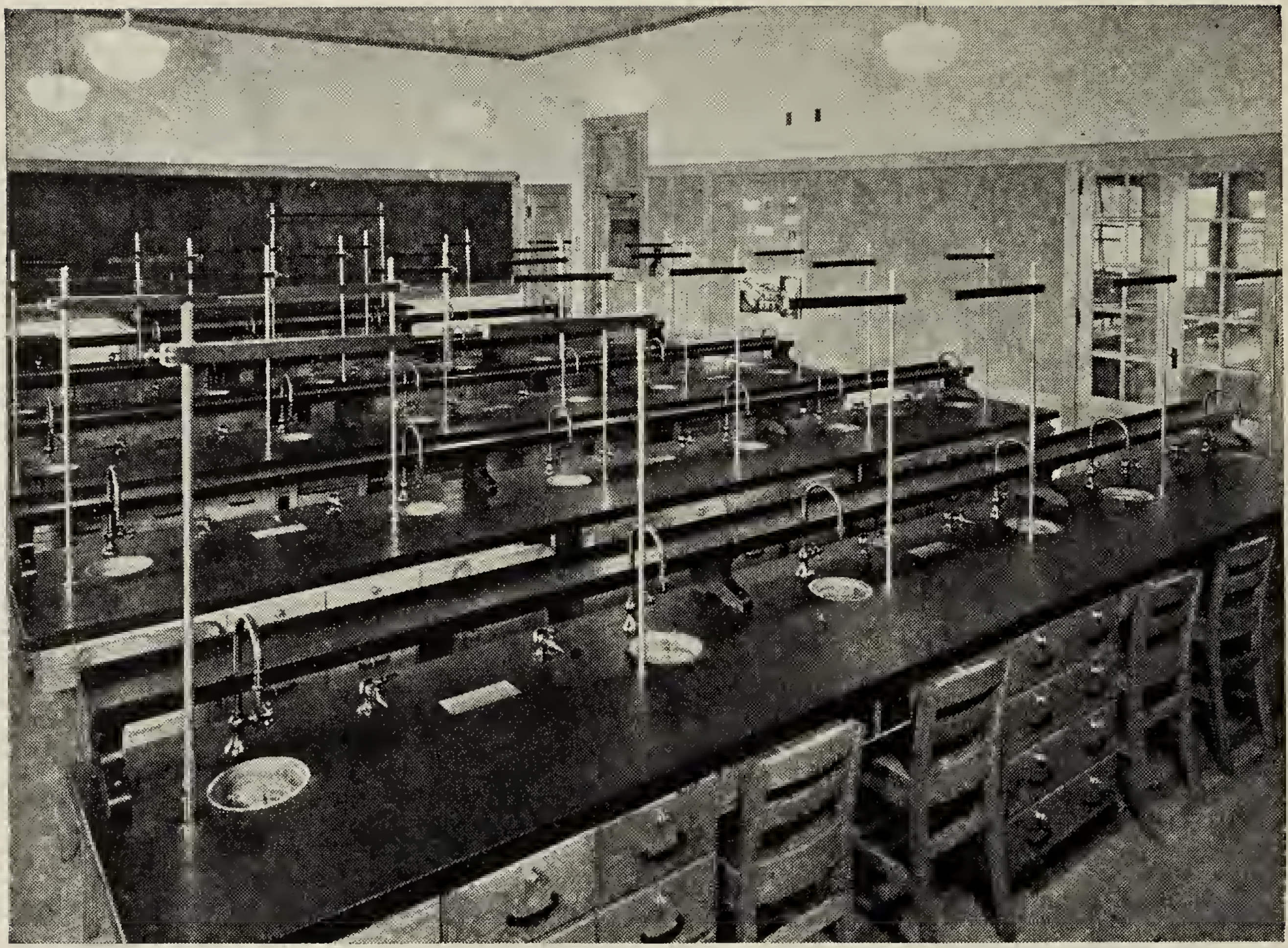

Fig. 8 Chemistry-Physics laboratory, North High School, Sheboygan, Wisconsin.

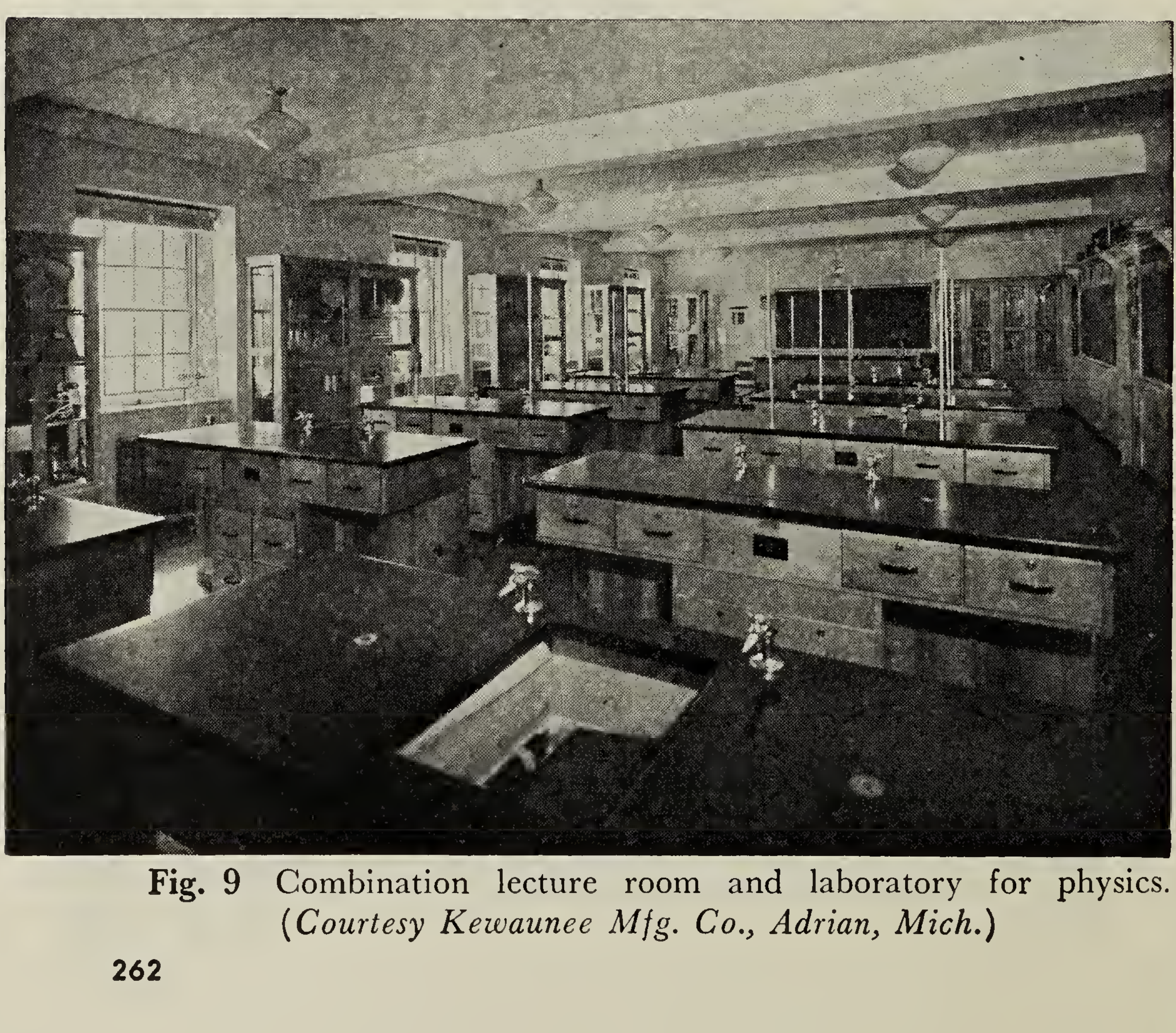

Fig. 9 Combination lecture room and laboratory for physics. (*Courtesy Kewaunee Mfg. Co., Adrian, Mich.*)

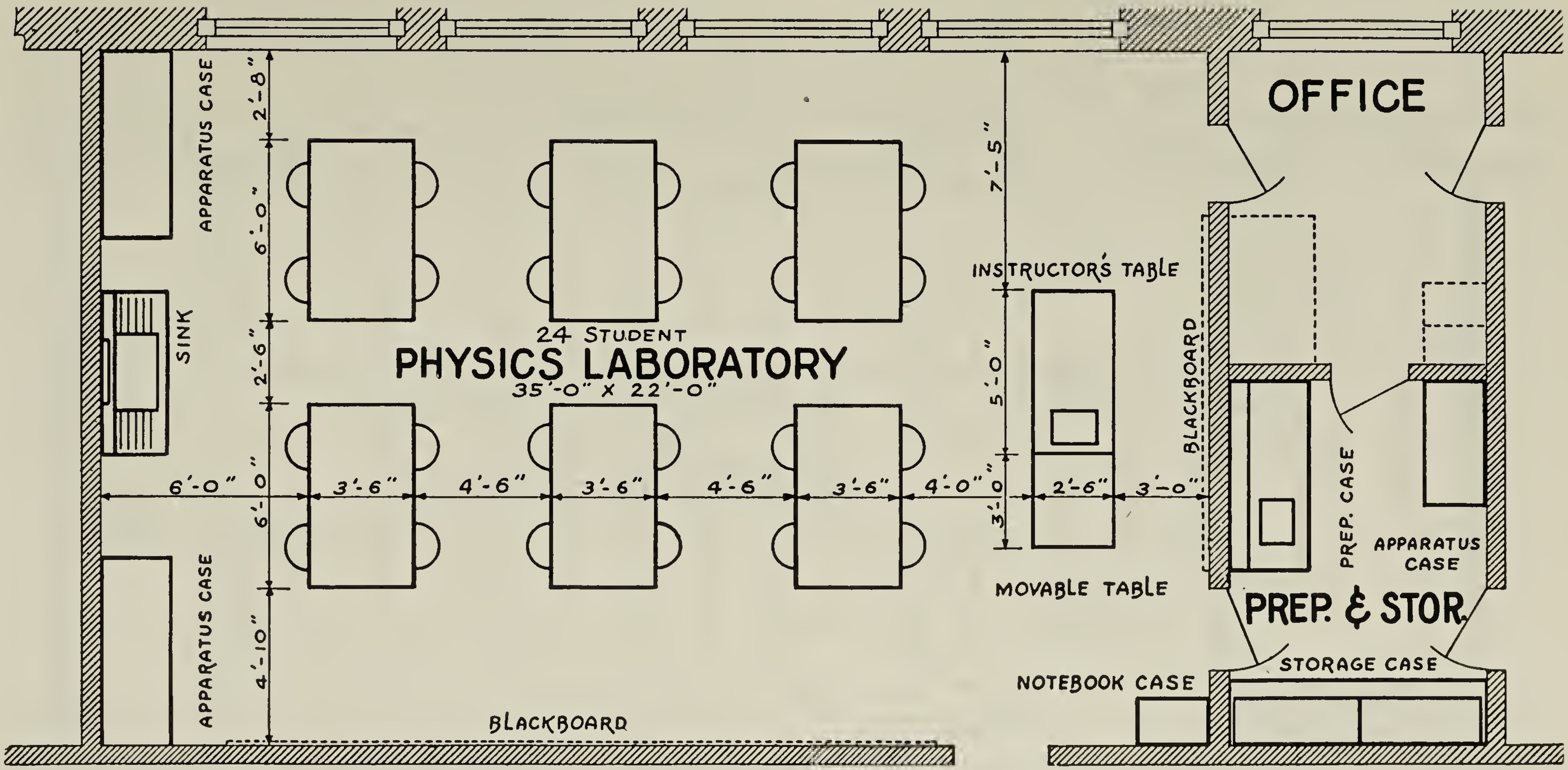
OFFICE
APPARATUS CASE
SINK
APPARATUS CASE
2'-8"
6'-0"
2'-6"
6'-0"
4'-10"
24 STUDENT
PHYSICS LABORATORY
35'-0" X 22'-0"
6'-0"
3'-6"
4'-6"
3'-6"
4'-6"
3'-6"
4'-0"
2'-6"
3'-0"
7'-5"
5'-0"
3'-0"
INSTRUCTOR'S TABLE
MOVABLE TABLE
BLACKBOARD
BLACKBOARD
PREP. CASE
APPARATUS CASE
PREP. & STOR.
STORAGE CASE
NOTEBOOK CASE

Fig. 10 Floor plan for a physics laboratory. (*Courtesy Kewaunee Mfg. Co., Adrian, Mich.*)

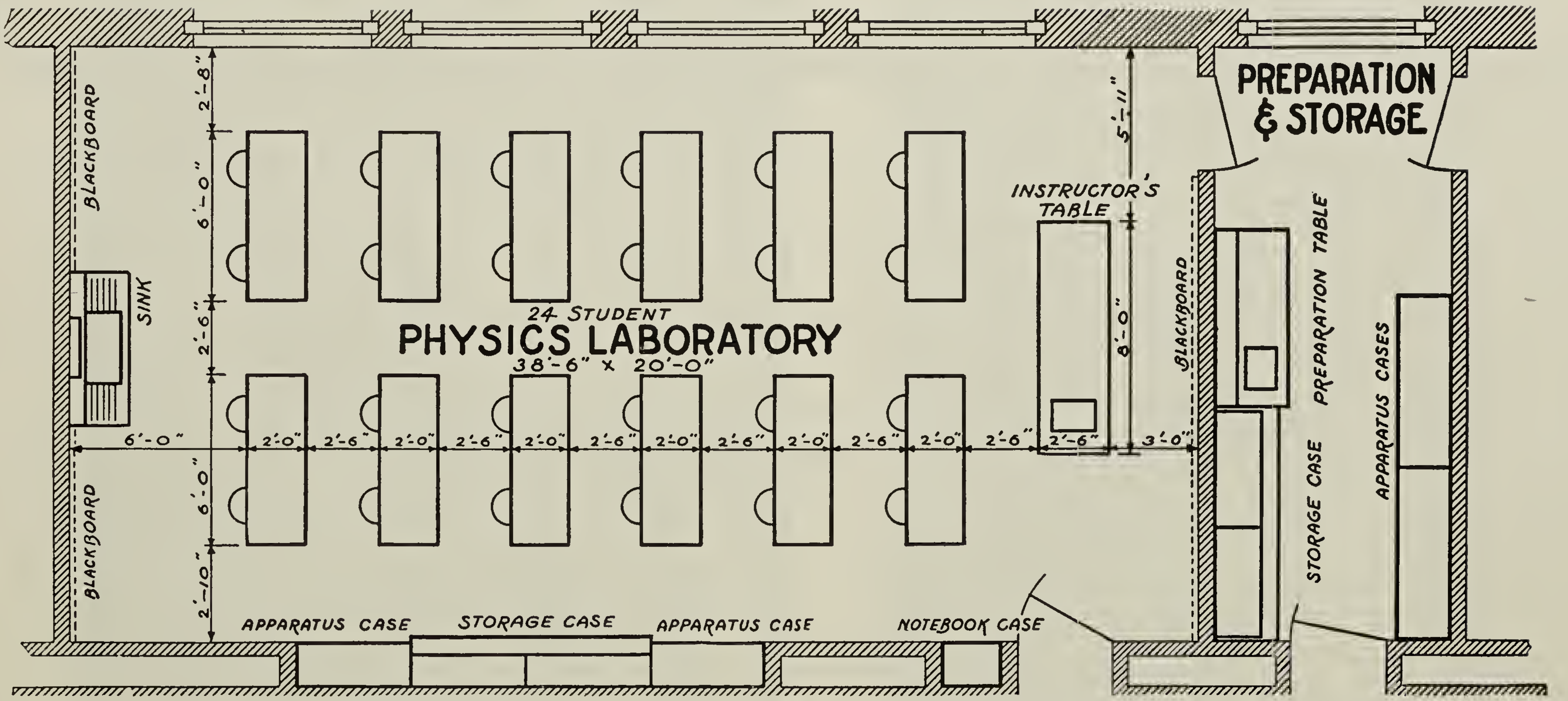
PREPARATION & STORAGE
24 STUDENT
PHYSICS LABORATORY
38'-6" x 20'-0"
INSTRUCTOR'S TABLE
BLACKBOARD
BLACKBOARD
BLACKBOARD
SINK
PREPARATION TABLE
STORAGE CASE
APPARATUS CASES
APPARATUS CASE
STORAGE CASE
APPARATUS CASE
NOTEBOOK CASE
2'-8"
6'-0"
2'-6"
6'-0"
2'-10"
6'-0"
2'-0"
2'-6"
2'-0"
2'-6"
2'-0"
2'-6"
2'-0"
2'-6"
2'-0"
2'-6"
2'-0"
2'-6"
2'-6"
3'-0"
5'-11"
8'-0"

Fig. 11 Floor plan for a physics laboratory. (*Courtesy Kewaunee Mfg. Co., Adrian, Mich.*)

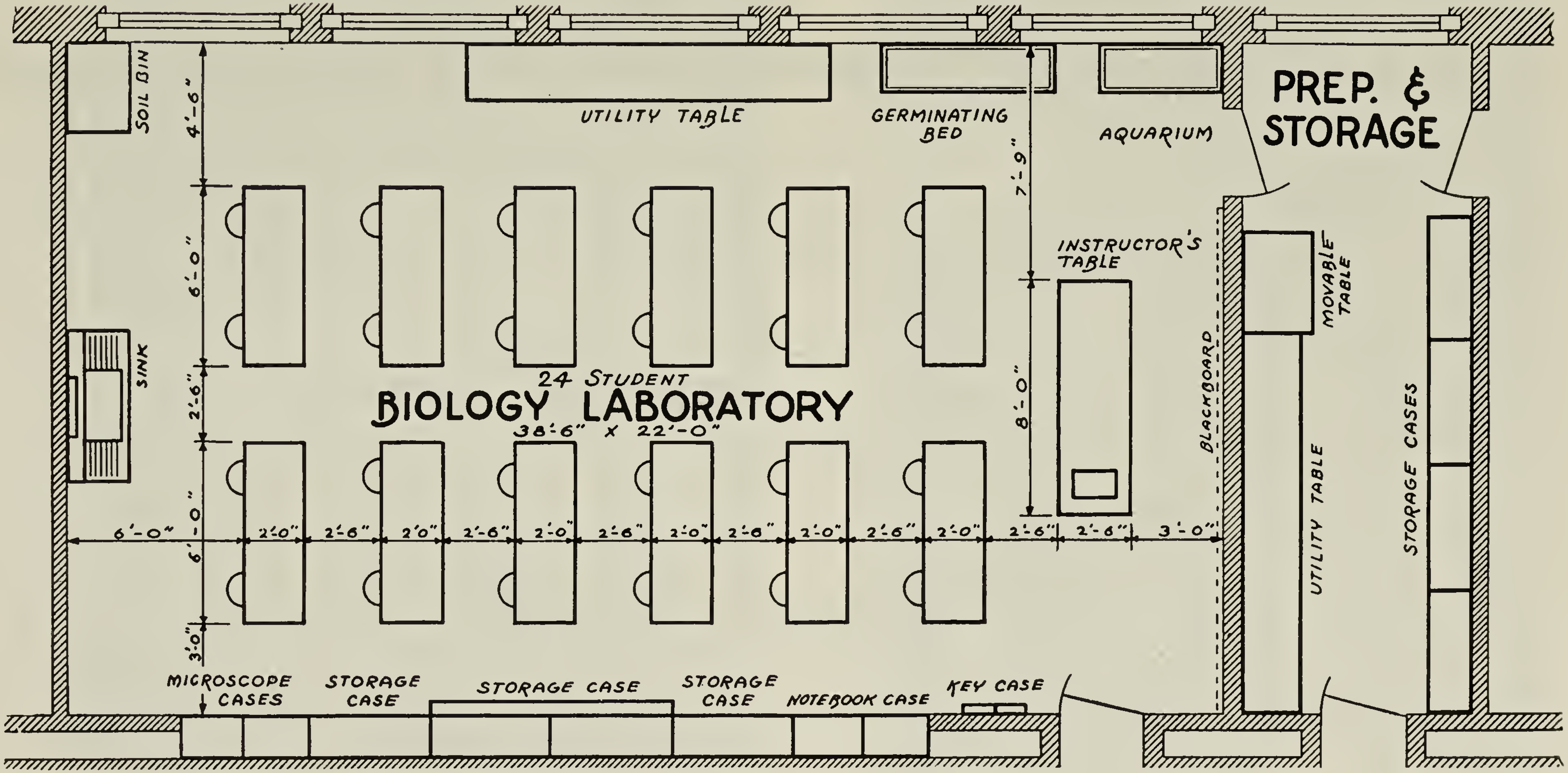
SOIL BIN
UTILITY TABLE
GERMINATING BED
AQUARIUM
PREP. & STORAGE
INSTRUCTOR'S TABLE
MOVABLE TABLE
BLACKBOARD
UTILITY TABLE
STORAGE CASES
SINK
24 STUDENT
BIOLOGY LABORATORY
38'-6" x 22'-0"
4'-6"
6'-0"
2'-6"
6'-0"
3'-0"
7'-9"
8'-0"
6'-0"
2'-0"
2'-6"
2'-0"
2'-6"
2'-0"
2'-6"
2'-0"
2'-6"
2'-0"
2'-6"
2'-0"
2'-6"
2'-6"
3'-0"
MICROSCOPE CASES
STORAGE CASE
STORAGE CASE
STORAGE CASE
NOTEBOOK CASE
KEY CASE

Fig. 12 Floor plan for a biology laboratory. (*Courtesy Kewaunee Mfg. Co., Adrian, Mich.*)

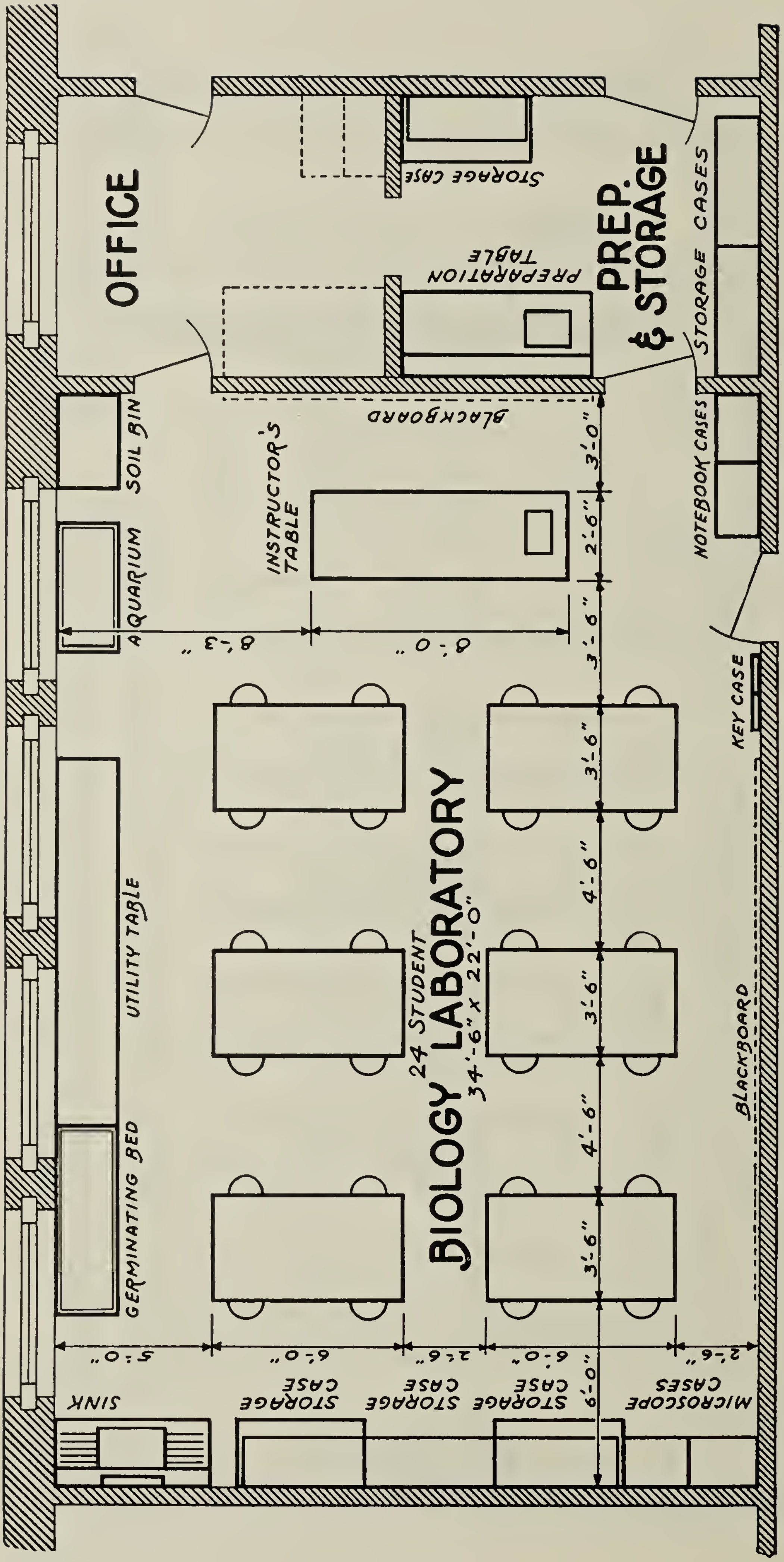
OFFICE
PREP. & STORAGE
STORAGE CASE
PREPARATION TABLE
STORAGE CASES
NOTEBOOK CASES
BLACKBOARD
INSTRUCTOR'S TABLE
SOIL BIN
AQUARIUM
8'-3"
8'-0"
3'-0"
2'-6"
3'-6"
KEY CASE
BIOLOGY LABORATORY
24 STUDENT
34'-6" x 22'-0"
UTILITY TABLE
GERMINATING BED
3'-6"
4'-6"
3'-6"
4'-6"
3'-6"
BLACKBOARD
SINK
STORAGE CASE
STORAGE CASE
STORAGE CASE
MICROSCOPE CASES
5'-0"
6'-0"
2'-6"
6'-0"
2'-6"
6'-0"

Fig. 13 Floor plan for a biology laboratory. (*Courtesy Kewaunee Mfg. Co., Adrian, Mich.*)

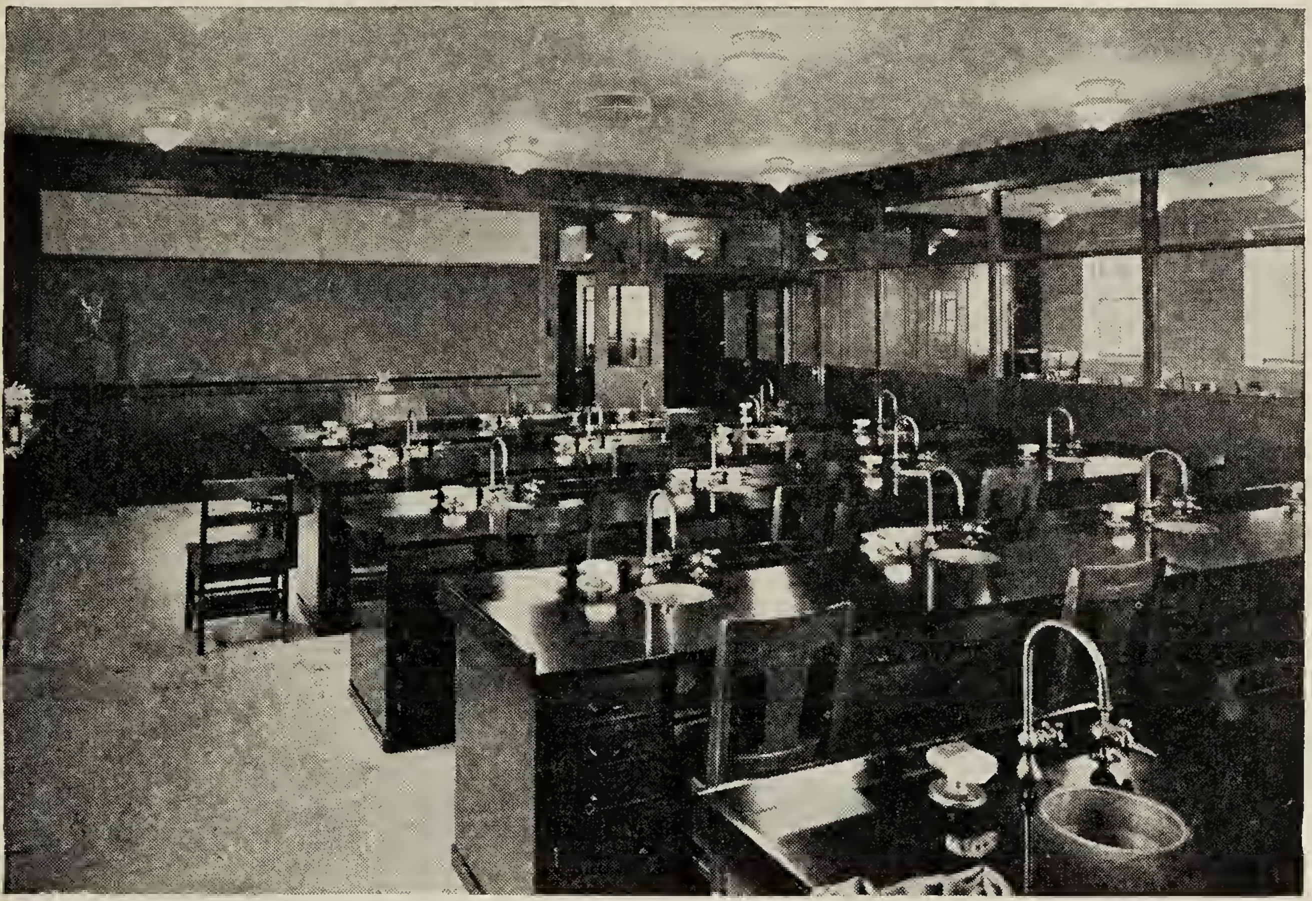

Fig. 14 Combination lecture room and laboratory for biology. (*Courtesy Kewaunee Mfg. Co., Adrian, Mich.*)

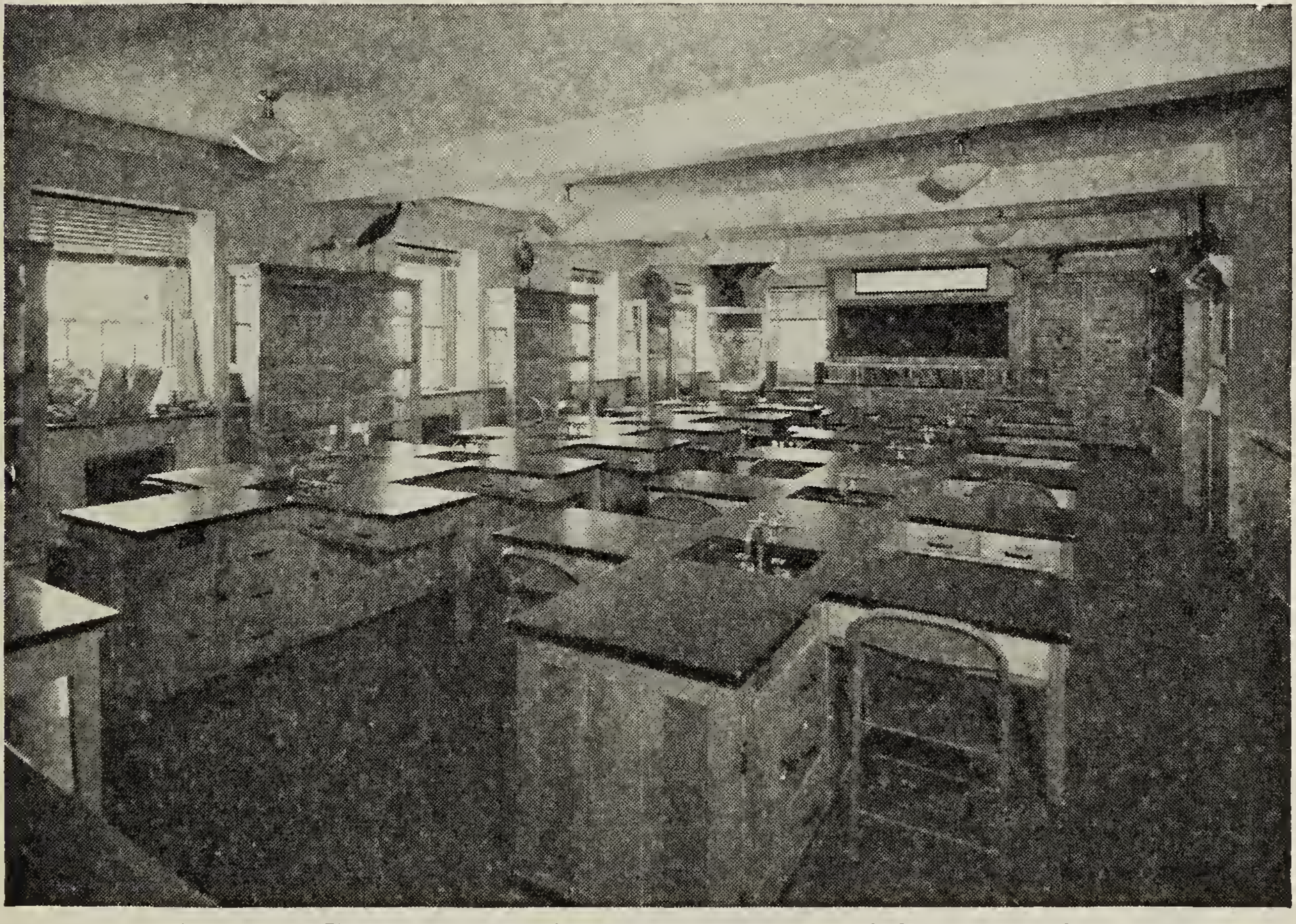

Fig. 15 Combination lecture room and laboratory for chemistry. (*Courtesy Kewaunee Mfg. Co., Adrian, Mich.*)

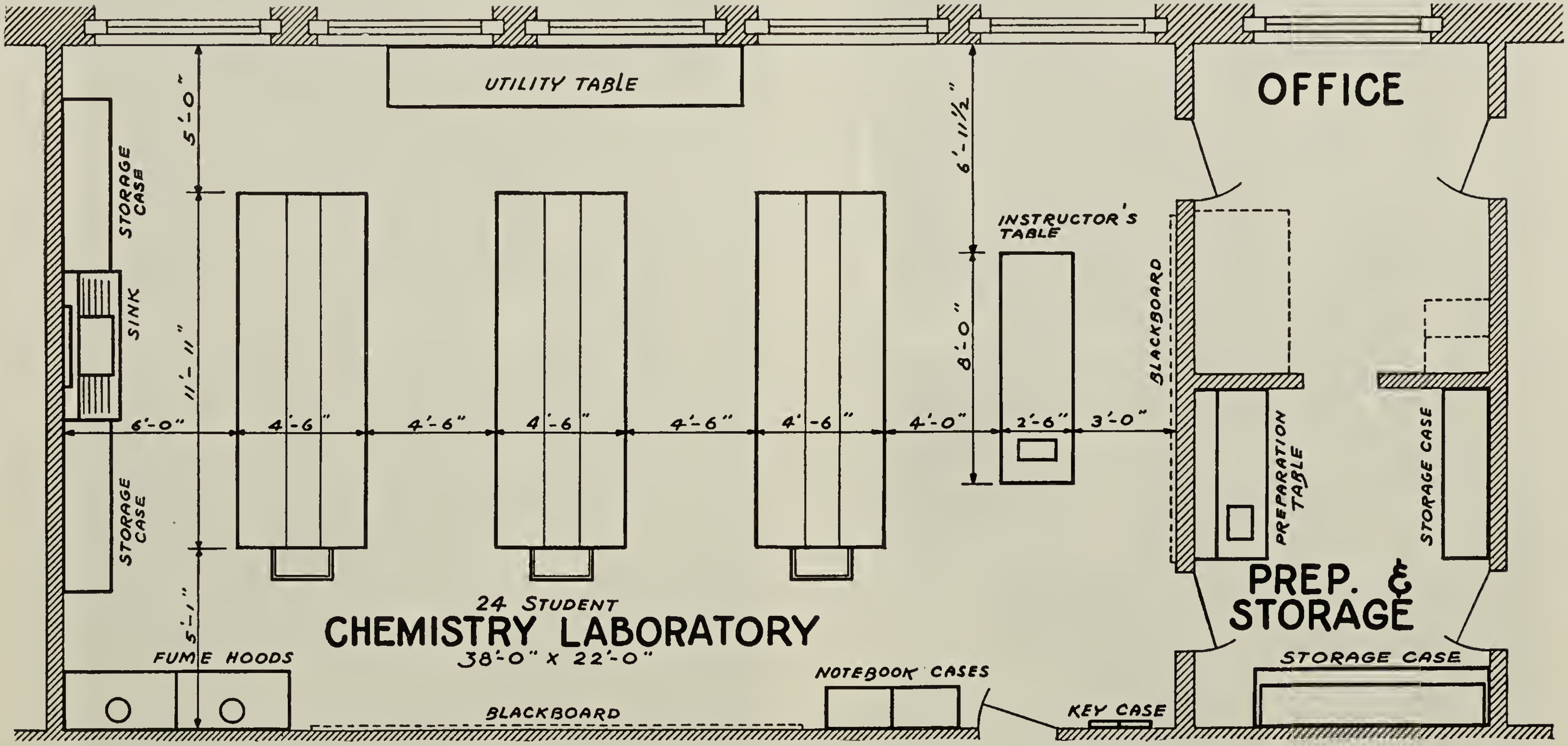
OFFICE
UTILITY TABLE
STORAGE CASE
SINK
STORAGE CASE
5'-0"
11'-11"
5'-1"
6'-0"
4'-6"
4'-6"
4'-6"
4'-6"
4'-6"
4'-0"
2'-6"
3'-0"
6'-11½"
8'-0"
INSTRUCTOR'S TABLE
BLACKBOARD
PREPARATION TABLE
STORAGE CASE
PREP. & STORAGE
STORAGE CASE
24 STUDENT
CHEMISTRY LABORATORY
38'-0" x 22'-0"
FUME HOODS
BLACKBOARD
NOTEBOOK CASES
KEY CASE

Fig. 16 Floor plan for a chemistry laboratory. (*Courtesy Kewaunee Mfg. Co., Adrian, Mich.*)

6. Visit a local high school or elementary school and write a critical evaluation of the facilities for science teaching in the light of the proposals found in this Chapter.
7. Assume that a school board has budgeted $700 for the permanent equipment in a general science room. Make specific plans as to how you would spend it.
8. List the pieces of permanent equipment needed in a well equipped preparation and stock room.

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Chapter 12

EQUIPMENT AND SUPPLIES FOR TEACHING SCIENCE

The function of the science teacher in securing equipment. One of the most important and time-consuming aspects of science teaching is the procuring and caring for equipment. While studies show that science is not the most costly subject in the curriculum to maintain, a considerable amount of money must be expended to equip for teaching science and some money must be expended annually for upkeep and replacement. Since funds for this purpose are limited in many school situations, it is very important that they be expended wisely. Thus it becomes necessary to weigh carefully each expenditure item in terms of its potential educational worth in the particular situation. In this chapter some of the practices used in the planning, purchasing, storage, and care of equipment will be considered.

Plans for purchasing equipment. It is very important that careful plans be made by the teacher for the purchase of equipment and supplies. Preliminary to the selection of equipment, it is necessary to ascertain in complete detail what is demanded for the proper teaching of the course of study or textbook. In many instances courses of study and textbooks will have a complete list of apparatus and supplies needed. These are often worked out on the basis of amounts needed for ten students, so that the teacher may determine rather accurately how much will be needed for a class of given size.

It is often the case that funds available for materials may not be sufficient to purchase everything needed. In this case the teacher must make a careful analysis of the most essential needs.

Some teachers have used the following classification in making this sort of an equipment analysis:

(1) Needs for demonstration work.
(2) Needs for laboratory work.
(3) General laboratory needs, such as tools, etc.

In some cases schools have found it more economical to deal with a single apparatus company. This plan has the advantage of building a relationship between customer and dealer which, over a period of years, may prove beneficial in matters regarding service and dependability. On the other hand, especially in larger school systems where there is a purchasing department, equipment lists are frequently sent out to competing dealers for bids. This plan has the advantage of lower prices on some items. If such a plan is used the science teacher must be very careful to write detailed specifications into the list for all items. This will tend to insure the quality of materials needed. Long experience by many teachers of science has proved beyond question that it is more economical to purchase the best quality of materials obtainable.

Sources of Equipment and Materials for Science Teaching

In planning equipment and supplies the science teacher should familiarize himself with the apparatus and equipment houses located nearest to him, because transportation costs are most commonly paid by the purchaser. For guidance on this matter the reader is referred to page 341 where there is a listing of apparatus and equipment houses in various parts of the nation.

The local community may contain a wealth of materials for science teaching. In no case should the science teacher depend solely upon apparatus houses for supplies. Dime stores, local industries, hardware stores, the local filling station, junk yards, auto graveyards, and the like may provide much physical equipment. Along with catalogs of apparatus houses, be sure to have in the science classroom catalogs from the leading mail order houses. It is often possible to secure supplies, such as copper wire, model steam engines, aquarium jars, etc. of good quality from mail order houses at a considerable reduction.

Determining the Kinds of Materials Needed

As a teacher approaches the problems of equipping any type of science room, certain general ideas should be kept in mind. At its best the science classroom is an artificial situation screened from the realities of living. Whatever the science teacher can do in supplying materials that tend to approach the real life situation should be done. Thus, other things being equal, pupils will profit more in studying a real life-size lift pump than in studying a glass model supplied by an apparatus house. The same thing is true of an automobile jack, a discarded auto engine, or transmission, and a myriad of other things. In the same way many items of equipment may be made in the school or home workshop that will be just as serviceable as much more expensive pieces obtained from supply houses. Later in this chapter more consideration will be given to homemade equipment.

As a guide to teachers, lists of essential equipment needed for elementary science, general science, biology, physics, chemistry, and physical science have been included on pages 447–457 of the appendix.

THE ANNUAL BUDGET FOR SCIENCE DEPARTMENTS

It is very essential that the science teacher show the administrative officials of his particular school the desirability of providing an annual budget for the purchase of replacement items and for the purchase of new equipment. Some materials used in science teaching, such as chemicals, biological specimens etc., are consumable and need to be replaced annually. There is also the inevitable problem of breakage of glassware and other fragile items.

Some teachers find it advisable to make out two budgets: one made up of annual replacements; the other based upon a long-time plan of building up the equipment of the department. In making out the second type of budget it is desirable to list the items in their approximate order of need and then to purchase them from year to year as the budget will permit. Many schools have a plan of breakage fees especially for such subjects as chemistry. The pupil is asked to make a reasonable deposit at the beginning of the year. At the end of the year a deduction is made for breakage and supplies and the balance is returned to the pupil.

The Storage of Equipment

Cases and storage space for equipment have been discussed in Chapter 10. It is sufficient to state here that storage of equipment and supplies should be carefully planned by the teacher. Items that are frequently in demand for general laboratory purposes, such as ring stands, clamps, beakers, etc., should be stored in places that are easily accessible to pupils so that it is not necessary for the teacher to be called each time a piece of equipment is needed by a pupil. Appointed pupil assistants can save the teacher much time in keeping such storage space in good order.

In a similar manner, it is often good economy from the standpoint of time to leave demonstration set-ups assembled from year to year. Such set-ups should be stored in cabinets as close to the demonstration table as possible to facilitate the assembly of materials for a class.

Some schools find it efficient from the point of view of time to store all general equipment needed for a year's experimental work in the laboratory desks. At the beginning of the year pupils are assigned desks and given keys. Each desk is supplied with a list of the equipment items to be found in the various drawers and cupboards of the desk. Items are checked at the beginning of the school year and again at the end. This provides an easy method for keeping student breakage accounts and in determining supplies which need to be ordered. It is also a simple way of keeping an inventory of a considerable amount of equipment.

The Equipment Inventory

It is very important that an accurate, detailed, and up-to-date inventory be kept for all equipment and supplies in the science laboratory. Such an inventory serves not only for purposes of school accounting but as a ready reference for supplies that need to be purchased and also as a reference index to where materials are stored.

Many different plans have been tried and many are no doubt in use. The one that seems to be most useful is a card-index system. A card is made out for each item of equipment as it is purchased. The following information on equipment items has been found useful:

Item	Purchased from C.S.Co.	Cat. No.	Case 9
Dry cells		10-8552	Shelf B

Date	On Hand	Ordered	No.	Price	Remarks
9/18/49	12	6/8/49	12	.40	Need to reorder—6/50 Loaned 3 to Shop Dept. 10/12/49

With such a card system in use the annual inventory may be taken quickly and effectively, while at the same time notations can be made for needed supplies. When such a card index has been completed it is wise to have a complete list of supplies typed up and filed in another place because of the danger of fire around a laboratory. As a rule, insurance companies demand detailed inventories in settling claims for losses.

The Care of Science Equipment

One of the duties of the science teacher is to keep equipment clean and in good repair. After each period of use a piece of science equipment should be carefully checked before it is returned to its storage place. This will save much time in the long run. Equipment that is used by pupils gets hard wear and may easily get out of adjustment. Teachers must plan time for making needed repairs and adjustments of apparatus.

To this end each laboratory should be supplied with a good kit of tools. This should contain the usual hammer, wrenches, screwdrivers, and pliers, and also a set of small pliers of different shapes, as well as a good set of jewelers' screwdrivers and forceps.

It is often necessary for the science teacher to convince the administrative authorities of the school that he has all of the routine duties of other teachers, such as looking over papers and tests, and that in addition he has an added job of keeping a large stock of equipment in repair. This takes time and the school administrator should face the fact and lighten the teaching load of science teachers accordingly. Another matter of time on the part of science teachers is also frequently overlooked by administrators. Good science teaching cannot be done unless the science teacher is given time in the school day to set up and tear down the equipment needed for work in the laboratory. Whenever possible science teachers should be provided with free time before classes to enable them to set up thoroughly the materials to be used by the class. The work day of the science teacher is a much more demanding type of day from the standpoint of time than is true in courses where books are the principal sources of information.

Providing Inexpensive Equipment for Science

The importance of homemade equipment. We do not have very much reliable information on the extent to which some elaborate piece of purchased equipment may be more educational than a simple piece of equipment improvised by the pupil or teacher. In fact, many science teachers feel that often the homemade piece has greater potentialities for educating than the purchased equipment because the pupil may be a participant in the actual making. There are many pieces of equipment, such as microscopes, vacuum pumps, thermometers, and the like which must be purchased. On the other hand there are many, many simple devices which may be made by pupils from tin cans, cigar boxes, electric light bulbs, scrap metal, and wire. There are also many experiments that may be done with materials found around the home or purchased from the dime store. No science class need lack for rich science experiences merely because equipment is not provided for by the school.

Every science room should be equipped with a work bench and a kit of tools that may be used by pupils in improvising equipment for science experiments. The scrap boxes of the woodworking and metal departments of the school will be found to be good sources of pieces of wood and metal that may serve some useful end in the science department. From any mail order house, dime or hardware store, screws, nails, tacks, staples, and other things needed for building may readily be obtained. Junk yards, garages, gasoline service stations, and auto graveyards are often potentially rich sources of old generators, motors, induction coils, transformers, storage batteries, thermostats, ball bearings, and many other useful parts.

There is a considerable amount of literature to be found on the subject of homemade equipment in the back issues of such magazines as *School Science and Mathematics, Popular Science Monthly, Popular Mechanics, The Science Teacher,* and others. Some articles from these magazines as well as a list of useful books on the subject are proposed at the end of this Chapter.

A few suggestions that may be used by teachers and pupils for improvising equipment are listed below:

(1) Flasks and beakers from old electric bulbs.
(2) Radio coils from wire and used cereal boxes (round).
(3) Simple telescopes from dime store lenses and mailing tubes.
(4) Simple telegraph sounder from bolts, wire, and a cigar box.
(5) Simple telegraph key from pieces of scrap copper, a bolt, and a wooden spool cut in half.
(6) An insect collecting net from a coat hanger, a piece of cheese cloth, and an old broom handle.
(7) Insect mounting boxes from cigar boxes.
(8) Insect stretching boards from cigar boxes.
(9) A motor from a board, nails, and wire.
(10) Simple magnets from the dime store or an old Model T Ford automobile generator.
(11) Ring stand from curtain rods, staples, and a wooden base.
(12) Bunsen burner from a wooden base and a short length of scrap pipe or brass or copper tubing.
(13) Pulleys from the dime store or hardware store.
(14) Wide-mouth Crisco or coffee jars for aquaria jars.
(15) Olive bottles for wide mouth bottles for collecting gas.
(16) A standard compass from a dime store, hacksaw blade, a cork, a piece of glass tubing and a needle.
(17) Vacuum experiments with a sink drain plunger (plumber's friend) from the dime store.
(18) Magdeburg hemispheres from two sink plungers.
(19) Electroscope for static electric experiments from dime store rubber balloons.

(20) Ammeters and voltmeters made from mounting battery, volt-ammeters obtained at the dime store.
(21) A simple laboratory generator from an old automobile generator.
(22) Wet and dry bulb thermometer from dime store thermometers, old ink bottle, and a piece of muslin.
(23) Gyroscope experiments with a dime store gyroscope.
(24) Light experiments with mirrors and lenses from the dime store.
(25) Storage battery from old battery acid, a jar and two pieces of old lead pipe that have been flattened out.

QUESTIONS AND EXERCISES

1. Use the equipment lists in the Appendix. Select some area of science teaching and make out what you would regard as an adequate science order list for a class of a given size.
2. Suppose that you were the head of a science department in the high school of a city of moderate size. Assume that you have science classes in all of the four high school sciences for which you must order equipment, as well as three elementary schools. What factors would you consider and how would you weigh each one so that you could make an equitable apportionment of the annual budget for science materials?
3. Discuss the values of homemade and purchased equipment.
4. Secure a catalog from a mail order house. Go through the catalog and make a list of items that could be used for teaching science. If possible, compare the costs of some of these items with similar items from an apparatus supply house.
5. If there is a dime store in your community make a survey of items that are carried which could be used in teaching science.
6. Select some textbook in one of the high school sciences or in elementary science. Go through the book and see how many experiments and demonstrations you can locate for which you can suggest improvised materials or equipment.

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SECTION III

Sensory Aids for Teaching Science

Chapter 13

THE PSYCHOLOGY OF LEARNING SCIENCE BY THE USE OF SENSORY AIDS

It has been said that sensory experience is the foundation of intellectual activity. Indeed it seems that all intellectual activity begins with and depends upon sense perceptions.

Human beings derive their experiences mainly from three sources: (1) direct sensory contact; (2) pictures or some other forms of representation of objects, phenomena, and relationshpis; and (3) oral or printed words or symbols. And of these three possibilities the third is of little value unless proper sensory experience is provided to serve as a basis for interpreting the oral and written words. It is not likely, for example, that the term "chemical action" would have much meaning to a person who has never heard the sizzling in a test tube or who has never seen precipitates form. What meaning would the term "atmospheric pressure" have to an individual who has never seen an exhausted tin can crushed by the weight of the atmosphere or who has never watched the lowering of a barometer in a partial vacuum during the varying stages of exhausting the enclosed air? The words "nucleus" and "vacuole" are vastly more meaningful after a student has studied biology and has seen cells under a microscope.

In science teaching we are greatly concerned with facts and concepts. Facts are statements which result from sensory perception. A biology teacher may exhibit a violet before his class and the pupils may state that the flower is blue. In stating this simple fact the pupils have associated the quality of blueness with the violet.

A concept may be simple or it may be complex. A pupil's concept of a flower might be that it is the reproductive center of the plant, that it has sepals, petals, stamens, and pistils, that it produces sperms and eggs, that the fertilized egg results in the new baby plant, and that the fruit develops from the flower. This would be a relatively complex concept.

Good science teaching requires (1) that the concepts to be developed in a science course be carefully defined by the teacher, and (2) that learning exercises and experiences be provided which will stimulate the pupils and which will make for permanency of the desired outcomes. If the teacher fails to do these things, much of the teaching is apt to be dry verbalism. Many of the pupils will hear and use scientific words without understanding the true meaning of the words, and furthermore they will associate together words and meanings which do not belong together. The data[1] given in the following table clearly illustrate this point.

Seventy-five college freshmen, shortly after they had entered college, were given a series of free-association tests. In this particular case they were instructed to write all they knew about bacteria. The students were stimulated to express themselves freely and they were given all the time desired.

The table gives the concepts and number and percentage of the seventy-five freshmen who expressed each concept.

Concepts expressed by less than four people are not given on the table. It will be noticed from an examination of the table that some of the concepts expressed are scientific and some of the concepts expressed are naive.

The data as analyzed in Table 2 are perhaps interesting and important but they do not give a complete picture of the situation. To get a true picture of the situation it is necessary to examine the "concept pattern" of each individual. In order that this chapter may be kept within reasonable bounds it is not advisable to do this for all seventy-five students, but we can examine a few samples. Graphic pictures of the "concept pattern" for bacteria held by four students are presented. These are designated as cases A, B, C, and D.

It should be noticed that in each case, except perhaps Case A,

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[1] These data are part of an unpublished research study conducted by Dr. Heiss.

TABLE 2

CONCEPTS EXPRESSED IN ANSWER TO THE STATEMENT, "TELL ALL YOU KNOW ABOUT BACTERIA"

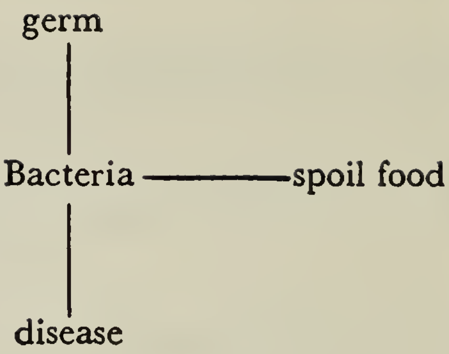
Concepts	No.	Per Cent
1. Bacteria are harmful and useful	48	64.0
2. Bacteria are tiny, invisible organisms	40	53.3
3. Bacteria cause diseases	38	50.6
4. Bacteria are germs (partly naive)	25	33.3
5. Bacteria multiply rapidly	19	25.3
6. Bacteria cause decay	18	24.0
7. Yeast cells are bacteria (naive)	16	21.3
8. Bacteria are nearly everywhere	16	21.3
9. Bacteria cause fermentation	15	20.0
10. Bacteria are animals (naive)	12	16.0
11. Bacteria are one-celled organisms	12	16.0
12. Bacteria thrive in warm places	12	16.0
13. Bacteria cause milk to sour	11	14.6
14. Bacteria are destroyed by intense heat	9	12.0
15. Bacteria are plants	9	12.0
16. Bacteria are tiny organisms	9	12.0
17. Bacteria cause foods to spoil	9	12.0
18. Bacteria are useful in cheese making	9	12.0
19. Molds are bacteria (naive)	8	12.0
20. Bacteria are on flies	7	9.3
21. Bacteria reproduce by dividing	5	6.6
22. Bacteria live in dark places	5	6.6
23. Bacteria need sun and light for growth (naive)	5	6.6
24. Bacteria are killed by sunlight	4	5.3

the students' conception of bacteria is a combination of scientific and naive notions. This is true for about 55% of this group of freshmen. This is not an exceptional situation. In fact, it was discovered that their concepts of such physical phenomena as light, heat, and electricity tended to be even more naive than scientific.

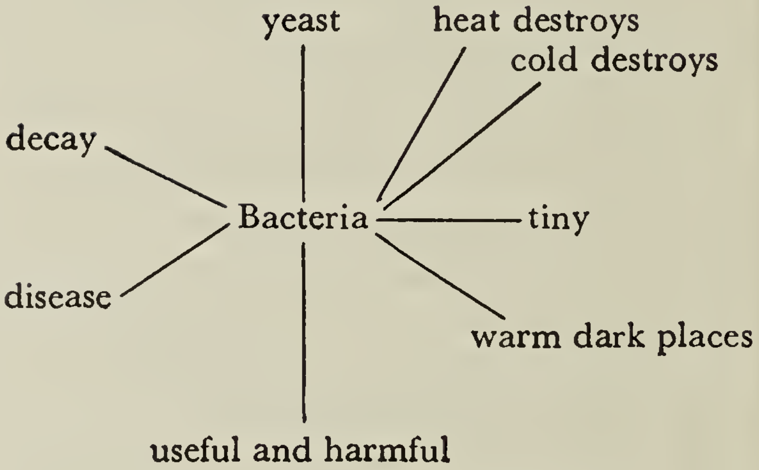
The writer does not know the cause of these effects but it seems a tenable hypothesis that verbalism constituted the major weakness in the teaching which produced these effects and that many of the pupils learned words without a sense of their real meaning.

An interesting example of verbalism due to insufficient experi-

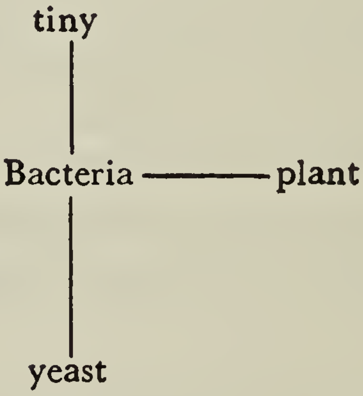
Case A
Science Courses
None


germ
Bacteria
spoil food
disease

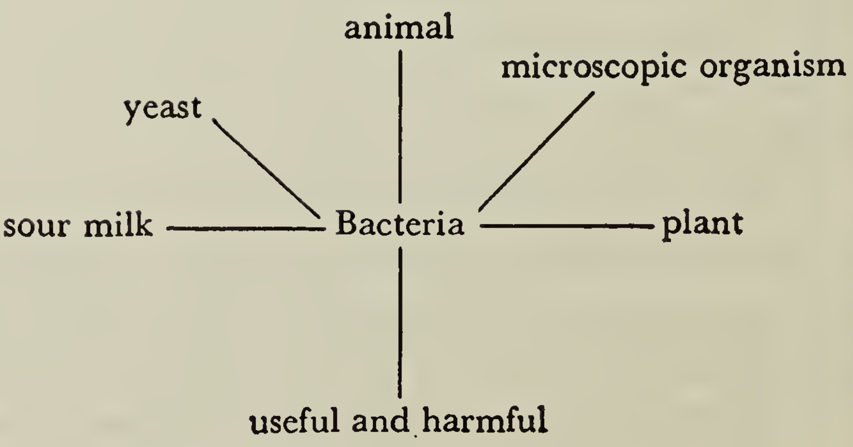
Case B
Science Courses
General Science (1 yr.)
Biology (1 yr.)
Chemistry (1 yr.)
Physics (1 yr.)


yeast
heat destroys
cold destroys
decay
Bacteria
tiny
disease
warm dark places
useful and harmful

Case C
Science Courses
General Science (1 yr.)
Chemistry (1 yr.)


tiny
Bacteria
plant
yeast

Case D
Science Courses
General Science (1 yr.)
Biology (½ yr.)
Zoology (½ yr.)
Chemistry (1 yr.)
Physics (1 yr.)


animal
microscopic organism
yeast
sour milk
Bacteria
plant
useful and harmful

ence is found in the story related by Messenger.[2] A little girl from the city went to visit people in the country. One day the little girl saw a cow chewing her cud beneath an evergreen tree. After watching the cow in action for some time she went into the house and said to the woman there, "Your cow is out under the Christmas tree chewing gum."

The program for teaching science as outlined in the *Thirty-First Year Book*[3] of the National Society for the Study of Education emphasizes major generalizations as one of the important objectives of science teaching. In the *Thirty-first Yearbook* it is proposed "that the curriculum in science for a program of general education be organized about large objectives, that understanding and enlargement of these objectives shall constitute the contribution of science teaching to the ultimate aim of education, and that the course of study be so organized that each succeeding grade level shall present an increasingly enlarged and increasingly mature development of the objectives."

In this connection it is of paramount importance for science teachers to bear in mind that major generalizations are abstractions. To tell pupils, for example, that "space is vast" without first having given them wide, varied, and concrete instruction about the heavenly bodies would be the dullest and poorest kind of science teaching imaginable.

It is important that science teachers clearly understand how generalizations develop. The following quotation[4] is clear and succinct on this point.

"Mental growth is in part the result of two apparently antithetical processes: differentiation and integration. Recent experimental investigation has established the fact that original behavior is highly integrated, that the organism responds to stimuli as a whole. For example, Lewin studied the responses of infants to various food substances and found that the very young child's reaction was a total bodily response. If lemon juice was fed an infant, the withdrawal was not merely a withdrawal of the tongue and head, but of the arms, legs, and torso. Similarly, if warm oatmeal was fed the infant, the response was a total bodily response toward the food, *i.e.,* the head, arms, legs, and torso were directed toward the desired food. The infant reacted in unitary, undifferentiated gross bodily movement toward or away from the stimuli.

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[2] Messenger, J., Franklin, *An Interpretative History of Education,* The Thomas Y. Crowell Co., New York, 1931, pp. 213–14.

[3] *Thirty-first Yearbook,* National Society for the Study of Education, Part 1, "A Program for Teaching Science," University of Chicago Press, 1932.

[4] Hoban, Charles F., Hoban, Charles F., Jr., and Zisman, Samual B., *Visualizing the Curriculum,* The Cordon Co., New York, 1937, pp. 16–17.

"Through the course of experience, differentiation of response develops out of total unitary response. This differentiation is not limited to gross bodily movements but is observable throughout the entire range of child behavior. The child will soon differentiate milk from water, the bottle from the breast, the mother from the nurse, the mother from the father, the other children from the parents, etc. Psychological objects are differentiated out of their environment as they attain significance to the child through his needs.

"It is in this elementary process of differentiation that visual aids have their value. Without concrete experience with objects there is no differentiation of this object out of vast environment. It does not exist as such for a child. The little girl who saw a cow standing under a Christmas tree chewing gum had little differentiated experience either with evergreen trees or with chewing movements not involved in actual eating. To the child Christmas trees and evergreen trees were synonymous because her only previous concrete experience with evergreens was in their relation to Christmas ceremonials. Similarly, her only previous experience with chewing response other than eating was chewing gum. Hence, to the little girl the cow was actually chewing gum under a Christmas tree.

"Upon the kindly explanation of the woman, the child's responses probably became differentiated. Evergreen trees came to exist in new relationships beyond their role in Christmas ceremonials through actual concrete experience with these trees. The child's responses to chewing gum were expanded beyond the limits of chewing gum through actual concrete experience in a new and now differentiated situation. Her experience had become richer.

"But differentiation is generally accompanied by a secondary process of integration. As experience with evergreen trees becomes differentiated into richer patterns through experience with firs, pines, spruces, cedars, etc., the abstraction of 'evergreen trees' develops through the emergence of a general pattern of trees having the common quality of a peculiar type of foliage which remains on the trees through the year. Through some common element or elements the various differentiated patterns of responses become integrated into a higher order of reaction. Each concrete experience becomes integrated into a subordinate relationship within higher-order response of 'evergreen trees.' Thus through the process of integration of differentiated concrete experiences that type reaction is developed which is known as abstraction and generalization. *The abstraction or generalization attains a richness of meaning to the extent that concrete experience is wide and varied, and to the further extent that this wide and varied concrete experience becomes integrated into a higher order of relationships.*"

Science teaching should also increase the pupil's vocabulary. Words are symbols which represent actions, things, and ideas. Thinking is carried on by the use of symbols, and it is impossible for us to think clearly about anything to which we cannot assign words. However, words (language) are relatively meaningless unless they grow out of concrete experiences. To be effective, science teaching should be built around concrete experiences which make abstract material meaningful. Powers[5] in extensive studies of the nature and difficulty of the vocabulary found in high-school textbooks has shown that the vocabulary burden of these texts is unnecessarily large. There is a trend toward simplification of the materials of science instruction and a trend toward the enrichment of science teaching through a liberal use of visual aids. Both of these trends should be carefully encouraged by administrators and teachers of science.

General Principles

Throughout this section of the book many different kinds of visual aids will be described. It is well to inquire, then, what is visual instruction? Is it a new method of teaching? Or is it a tool?

Visual education is not a new subject or a new method of teaching. Visual instruction implies the presentation of knowledge to be gained through seeing experience. It is a means to an end. Its purpose is to provide for enrichment of education and learning through maximum use of the sense of sight. Visual instruction involves the use of all types of visual aids, such as field trips, objects, specimens, models, exhibits, flat pictures, charts, graphs, stereographs, lantern slides, opaque projectors, still films, microscopes, and motion pictures.

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[5] Powers, S. R., "The Vocabularies of High School Science Textbooks" and "A Vocabulary of Scientific Terms for High School Students," *Teachers College Record,* XXVI: 1925, 368–92 and XXVIII: 220–45.

Sensory aids effect an economy of time in learning. Written and oral language are the media by which learning materials are most commonly presented. Language, however, has many limitations that may contribute to learning difficulty. The use of words alone cannot make the construction and operation of a machine as meaningful to the learner as the object itself or perhaps an adequate model or picture. There are many situations in science which are laborious to describe and exceedingly difficult to make clear when only verbal language is used. Certainly a visual demonstration is more concrete and more interesting than when a science teacher attempts to cover the same material solely by the use of words.

Visual devices supplement the learner's limited experience and background. There are many areas of the physical world that pupils are unable to visit or explore. A visit to a museum, the examination of a collection of selected pictures, the viewing of an educational movie, the graphic and pictorial materials in his textbook all help to enrich and expedite his learning.

The use of visual aids does not in itself guarantee good teaching. Visual techniques require careful planning and ingenuity. The following general principles have been developed as general guides to the use of visual aids.

The exposure of pupils to visual aids will not in itself guarantee successful teaching. Visual aids must be adapted to the intellectual maturity of the pupils and to the nature and extent of the pupil's previous experiences. Furthermore, most visual aids have certain psychological limitations. Flat pictures, for example, lack depth and are frequently not true in color or in size. The teacher of science should become thoroughly familiar with the advantages and limitations of all the various types of visual aids.

Visual aids are not meant to be a substitute for oral and written methods of gaining knowledge or direct experiencing. Rather they are to be used to supplement and enrich other methods of learning.

An experimental investigation by Jayne[6] with a large number of pupils studying general science supports this guiding principle. Jayne studied the informational gains made by pupils listening to a lecture as compared with gains made from seeing a silent motion picture presenting the same science content. From his data Jayne arrives at the following conclusion. "The study seems to indicate that the increased learning which comes from the use of visual materials, as determined by many investigations, is not due primarily to the visual experience alone, but rather to the adding of a visual experience to other teaching procedures. Teachers probably are not justified in assuming that the visual experience is so effective that other types of experience should be eliminated in its favor. The most effective learning will probably come from the proper integration of many types of experience—not from concentration upon one."

Visual instruction in the classroom should not be confused with entertainment. Visual aids are not meant to eliminate work or thought. They should be used to make work more interesting and more meaningful and to stimulate pupils to greater activity and thinking.

Visual aids vary in their effectiveness in direct proportion to their degree of reality. A biology teacher, for example, in teaching about butterflies would find an actual specimen of a butterfly more effective than a photograph or a slide because the specimen is reality. If the teacher had no specimen of the butterfly but used a photograph or slide instead, the lesson would be more effective than if no visual aid were used.

QUESTIONS AND EXERCISES

1. What does the statement "sensory experience is the foundation of intellectual activity" mean to you?
2. What is the meaning of the term "verbalism"?
3. Do you think it is good science teaching to have pupils blindly memorize what a science textbook says?

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[6] Jayne, Clarence D., "A Study of the Learning and Retention of Materials Presented by Lecture and by the Silent Film," *Journal of Educational Research,* XXXVIII: 47–58, 1944.

4. Suppose you were to teach a lesson on the working of a gas engine. Which of the following methods would you consider the best one to use:
   (a) a verbal description of the gas engine?
   (b) a verbal description plus the use of a demonstration engine?
   (c) a verbal description plus the use of a picture of a gas engine?
5. Why does the exposure of pupils to visual aids not in itself guarantee successful teaching?
6. Generalizations are abstractions. "Space is vast" is a generalization. Could you plan a series of lessons through which ninth grade pupils would arrive at a rich understanding of this generalization?

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Chapter 14

USING COMMUNITY RESOURCES IN TEACHING SCIENCE

The modern science teacher uses the resources of the community for purposes of enrichment and supplementation, wherever such correlation can practically be made. The extent to which community resources should be used will depend upon their potential usefulness in achieving the major goals of science instruction.

A careful survey of the opportunities offered by any rural or urban community will reveal an extensive array of materials and phenomena which may be used by science teachers. The following situations in cities, towns or rural areas are suggestive of the wide variety of community resources appropriate for teaching science.

1. Museums, zoological parks, and botanical gardens.
2. Chemical and other industrial plants.
3. Airports.
4. Telephone buildings, radio stations, and power plants.
5. Engineering projects.
6. Weather bureaus.
7. Bird sanctuaries.
8. Near-by farms, gardens, vacant lots, and woods.
9. Mines and quarries.
10. Lake or ocean shorelines.
11. Caves, gaps and other interesting natural phenomena.
12. Ponds, lakes, streams, and bogs.
13. Observatories and planetariums.
14. Field trips to observe agents of weathering and erosion at work.
15. Greenhouses.
16. Stores and markets.
17. Exhibits of garden clubs and flower shows.
18. Departments of health and sanitation.
19. Junk yards.

20. The constellations and other heavenly bodies visible to the naked eye at night.
21. Water purification plant.
22. Milk pasteurization plant.

The School Journey

The school journey is any school exercise designed to provide complete sensory experience with things and phenomena which cannot be brought into the classroom. It involves the taking of pupils to places where the subject matter of instruction may be studied firsthand.

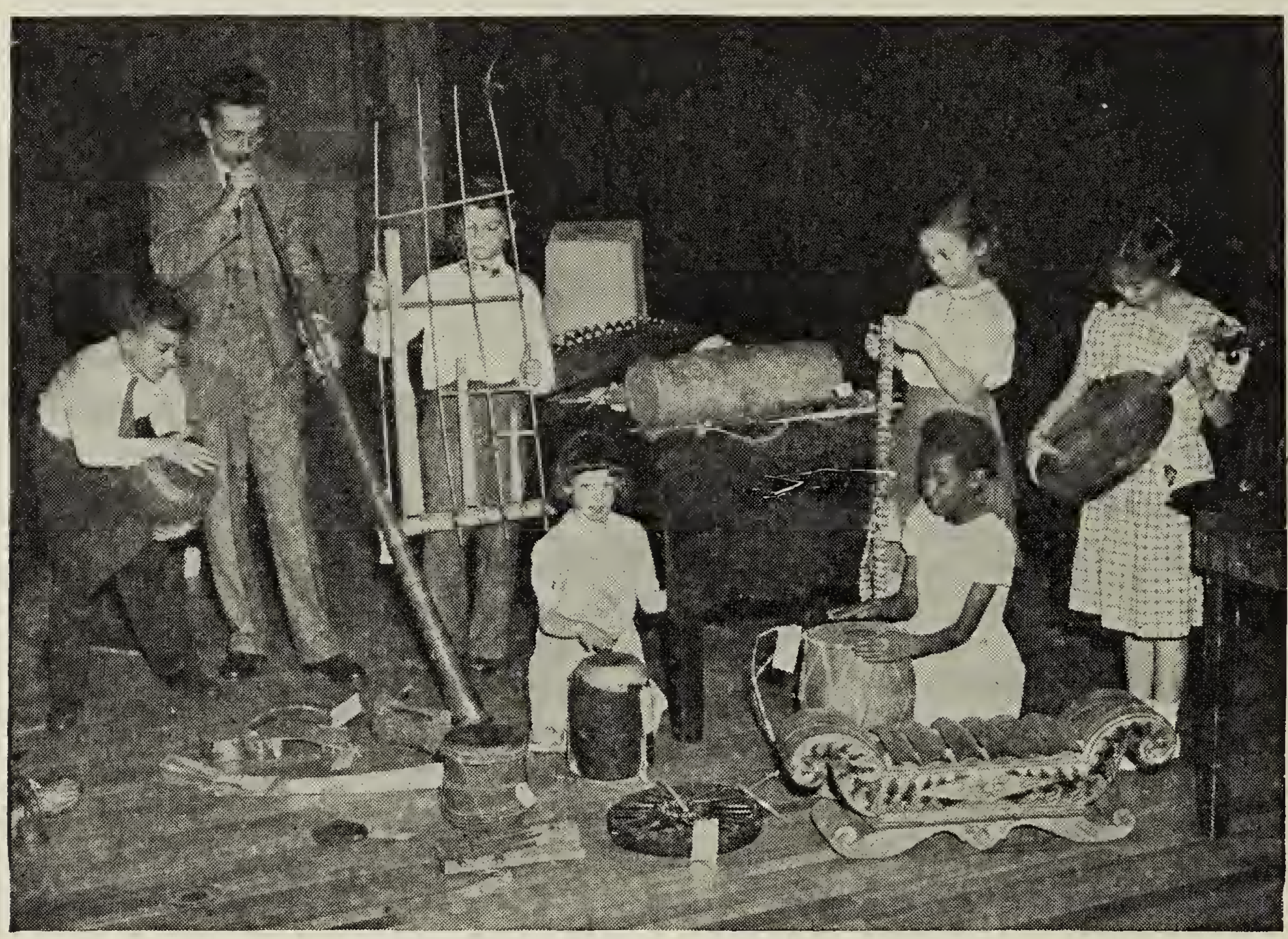

Fig. 17 Children take an active part in demonstrations of primitive musical instruments at the American Museum of Natural History.

The term "school journey" as used here includes exercises which among science teachers are frequently spoken of as field trips or excursions. It implies a broader meaning than that sometimes applied to field trips and it is used to cover any instructional work done outside the classroom.

The school journey as a teaching technique is unique in that it gives pupils firsthand experiences with things and phenomena which cannot be brought into the science classroom. It is the only teaching technique which makes it possible for pupils to see materials and phenomena in their true relationship. Motion pictures, models, lantern slides and other sensory aids should be used as substitutes for first-hand experiences only when school journeys are not possible or feasible.

Advantages of the school journey.[1] A strong recommendation for school-journey practice is the fact that it is a coöperative enterprise. Teacher and children join in the project. The child is the active agent; the teacher the wise counselor and skillful guide. Through the teacher's generalship, initiative can be stimulated, powers of self-dependence can be cultivated, and this type of instructional aid made an effective tool in achieving the objectives for which school work is intended. Among the advantages of the school journey are the following:

(1) It shows natural phenomena in their proper settings.
(2) It tends to blend school life with the outside world, putting pupils in direct touch, under learning situations, with things, persons, movements, relationships, environments, occupations, tendencies, trends, functionings.
(3) It stimulates interest in natural as well as man-made things and situations, and enables pupils to know intimately their environment.
(4) It promotes the consideration of problems arising from individual and group participations in natural social settings.
(5) It affords opportunities to develop keenness and accuracy of observation and to experience the joy of discovery.
(6) It sets up a "challenge" to solve, and this stimulates constructive, creative thinking.
(7) It helps children to organize their knowledge.
(8) It develops initiative and self-activity, making pupils active agents rather than passive recipients.
(9) It provides helpful practices, and thereby cultivates the habit of spending leisure time profitably.
(10) It serves to arouse ambitions and to determine aims.
(11) It provides for valuable correlation of subjects.
(12) It effects a genuine socialization of school procedure.

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[1] The list of advantages, the organization and procedure, and the types of school journey lessons have been adapted from Educational Monograph, *Visual Education and the School Journey,* Department of Public Instruction, Commonwealth of Pennsylvania.

Purposes. Among the definite purposes for which school journeys or field trips may be conducted are:

(1) To serve as a preview of a lesson and for gathering instructional materials.
(2) To create teaching situations for cultivating observation, keenness, discovery—to encourage children to see and know the things about them.
(3) To serve as a means of arousing specific interests as in birds, trees, animals, the heavens, and industrial processes.
(4) To supplement classroom instruction; to secure definite information for a specific lesson.
(5) To verify previous information, class discussions and conclusions, or individual experiments.

Organization and procedure. In planning school journeys, a first essential is to make a survey of the immediate and neighboring surroundings in order to list all available materials. From such a survey teachers may familiarize themselves with their location and avenues of approach, as well as special features and the purposes they will serve.

This will require several exploratory expeditions. Teachers find survey work very stimulating. Discovery of new material is constantly interesting. When a survey is made by a supervisory official and the teaching corps, it becomes an ideal project. The staff is divided into groups. Each group selects its leader and becomes responsible for a certain area. Reports are made by these groups at teachers' meetings, and the composite report furnishes the necessary data for the entire district.

The number of journeys will depend upon the importance of materials and their relationship to the curriculum. Lessons on or near the school plant can be conducted in the regular recitation period; those within easy access of the school, after school, or the last period of the morning or afternoon; if at some distance, on a Saturday morning or a holiday. Some journeys require an entire day. Proper arrangements should be made with the school authorities. For trips to museums, public buildings, or industries, it will be necessary to make arrangements for guides, vehicles, etc.

School journey technique. The school journey, though highly valuable and a major visual aid, is but too rarely used. The reason is, perhaps, that teachers do not know school-journey technique. They too often fail to see the material which is close at hand; and possibly have not, in their teacher preparation, learned how to use it in instruction.

The following technique is recommended for organizing and conducting a school journey:

First step. Evaluate the advantages in order that as many as possible may be profitably utilized.

Second step. Determine the purpose for which the journey is to be conducted; or a possible combination of purposes.

Third step. Examine survey data for
- (1) Materials that will develop correct concepts.
- (2) Situations around which activities may be organized that will assist pupils in developing desirable attitudes, skills, and habits.

Fourth step. Make necessary arrangements with
- (1) School authorities.
- (2) Owners or representatives of places to be visited.

Fifth step. Initiating the journey.
- (1) Develop the need—during class discussion, or group activity, etc.
- (2) Have pupils definitely fix the aims.
- (3) Teacher preparation—familiarity with place, route, features, necessary reference materials.
- (4) Pupil preparation.
  - (a) Equipment—notebook, field glasses, proper clothing, etc.
  - (b) Study of reference material.
  - (c) Spirit of alertness, determination to meet and solve situations.

Sixth step. Instruction *en route* and the lesson.
- (1) On the way—pupils alert, at times noting and listing things seen; teacher a constant guide.
- (2) At the place—the definite lesson; pupils utilizing initiative, self-activity, observation, teacher guiding the organization of pupil observation.
- (3) The return—pupils exchanging ideas, freely discussing experiences, asking questions, etc.
- (4) The follow-up.
  - (a) Reports from pupils.
  - (b) Discussion of reports; questions by pupils and teacher; evaluating reports.
  - (c) Coördination of the work.

Seventh step. Appraise the lesson.

(1) Teaching values.
  (a) Enriching and vitalizing.
  (b) Motivating.
  (c) Socializing.
(2) Constructive influence on pupils' attitudes, habits and skills.

Dr. Armin K. Lobeck[2] of Columbia University makes the following practical suggestions pertaining to school journeys:

(1) Do not spend too much time getting to the scene of action. The party must be fresh physically and eager mentally to discover what it is all about.
(2) Do not crowd too much into a single afternoon. One good, rounded idea or combination of ideas is best. Concentrate on this and play it up in as dramatic a way as possible. Play with its facets. It is very likely that the ground will be familiar to most members of the group. They will think they know all about it. Startle them then by bringing out or having them discover what hitherto had been hidden from their understanding.
(3) Members of the group must participate actively and not be passive listeners. They must have something to do, each one of them; pace off distances, determine locations, measure thicknesses of formations, look for boulders of a certain type, seek for fossils, note the character of the vegetation, or discover the typical occupation of the region, whether in building or farms. The pupils should make sketches, drawings, plans, maps, take pictures, and write descriptions.
(4) Keep the whole proposition simple, or at least make it seem so. Before leaving one place of observation, go over systematically all that has been observed, sum it up in typical form, and leave the job finished in shipshape fashion. Each member must feel that he has conquered the situation, that he understands it, and that there is nothing quite so interesting as to tackle another spot where this routine can be repeated.

Pitluga[3] has made an intensive study of how school journeys may be used to enrich the science experiences of children in the middle and upper grades of the elementary school. His study offers guidance in the effective use of the field trip as a teaching technique, as well as information and suggestions on how school journeys may be carried out.

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[2] Lobeck, Armin K., "The Organization of Field Excursions," The National Education Association, Department of Elementary School Principals, *Thirteenth Yearbook, Aids to Teaching in the Elementary School,* XIII:274–77.

[3] Pitluga, G. E., *Science Excursions into the Community,* Bureau of Publications, Teachers College, Columbia University, New York, 1943.

Typical school journeys. The following lessons in science which have been reported in the educational monograph, *Visual Education and the School Journey,* Department of Public Instruction, Commonwealth of Pennsylvania, represent successful techniques in organizing and conducting school journeys.

A TRIP TO THE LOCAL PAPER MILL

Previous work:

The class has been discussing the making of paper

(a) The materials—wood, rag, straw, etc.
(b) The processes involving science.

It was decided to visit the local paper mill to observe the application of science in the making of paper.

Arrangements for visit:

A committee from the class secured permission to visit the mill and arranged for the services of a guide who would explain everything connected with paper making.

Preparation:

The teacher visited the mill and studied the paper-making processes previous to the trip by the class.

The class was instructed to exercise extreme care when near moving or stationary machinery; to ask the guide reasonable questions regarding the materials, machinery, and processes; to give respectful attention to the guide when making explanations and to show appreciation for all courtesies and services.

At the mill:

The class was met by the guide, who first of all pointed out the logs of pulp wood piled in the yard.

GUIDE. From what kind of trees were these logs cut?
PUPIL A. They look like pine.
PUPIL B. I think they are hemlock.
GUIDE. They are spruce.

Upon entering the mill, the first object of interest was the *chipper* with its revolving knives. This machine breaks the wood into chips about one ond one-half inches long.

The second process was then explained. The small chips passed from the chipper into the *digesters.* Here the chips are cooked with calcium bisulphate under steam pressure. The cooking dissolves the binding materials and leaves the pure cellulose fiber. This is called *pulp.*

From the digesters the group passed to the *cleaners*. As the pulp moves through the cleaning troughs, the cooking acid, undigested particles, and dirt are removed.

After being thoroughly cleaned, the pulp is subjected to the bleaching action of chloride of lime. This turns the pulp to a beautiful shade of white.

The next process takes place in the *beaters*. Through the rotation of the *beater roll* the fibers are so frayed that they lock together. Filler and sizing are added while the pulp is in the beaters.

PUPIL. What materials are used for filler?

GUIDE. Talc and china clay are used for fillers and liquid rosin for sizing. (The guide shows specimens of talc, china clay, and liquid rosin for sizing.)

After the beating process, the stock is passed through Jordon Refining machines and thence to the Fourdrinier machine where the water passes off and the drying process takes place through drainage and evaporation.

It next passes through the *calender,* where the pulp in moving through a series of rolls is given the proper surface and finish. The paper is then wound into rolls and passed into the finishing room, where it is cut into different sizes and prepared for shipment.

Check:

Next day the following true-and-false test was given. This was to form the basis of discussion for the succeeding lesson.

(1) Jack pine and poplar trees are two of the woods used in making wood pulp.
(2) Pulp is formed by adding water to wood chips.
(3) All sawdust resulting from the wood chipping is used as fuel.
(4) In the digesters, the impurities are dissolved by chemicals.
(5) A Jordon machine makes the pulp into sheets of paper.
(6) Water is drawn from the paper pulp by means of suction.
(7) China clay and talc are the only fillers used.
(8) A mixture of rosin and sodium hydroxide is sometimes used in glazing the paper.
(9) Bleaching is caused by exposing the pulp to the sun.
(10) Small amounts of bark may be used in wood pulp manufacture.

A STUDY OF BIRDS

JUNIOR HIGH SCHOOL

1. Field Project, Study of Summer Birds
Locality, Northern Pennsylvania
Season, Summer Months

2. Committees appointed to take charge of trip:
    A. Planning committee
    B. Committee on what to look for
    C. Supplementary committee
    D. Final report committee
3. Plan:
    A. A committee of pupils planned the trip. The class was organized into three groups of five students each. One group was to visit a local park; another, a nearby farm; the third, a wooded hillside. Each pupil was requested to bring a pencil, notebook, and field glasses. Directions were given each group as to what they should observe.

       At the end of a definite period of time, the leaders were expected to make a report of their respective groups. A supplementary committee was instructed to secure from books such information as could not be gathered on the trip.
    B. What to look for:
        (1) Kinds of birds
        (2) Characteristics
            (a) Color
            (b) Size
            (c) Shape of head
            (d) Color of legs and feet
            (e) Formation of wing and tail
            (f) Peculiarities
        (3) Behavior
            (a) Action when observed
            (b) Method of flight when seen
            (c) Does it run, hop, or walk while on ground?
            (d) Song
                (1) Musical
                (2) Unmusical
                (3) Varied
        (4) Nests
            (a) Nests containing eggs
            (b) Nest containing young
            (c) Empty nests
            (d) Material of which nests are made
            (e) Location
        (5) Importance to man
    C. Summary of group reports.

The following narrative was reported from one of the groups:

As the note of a bird was heard one of the party exclaimed, "I wonder where it is?" We listened and found the song began with a trill and ended in a call. We continued slowly and finally found the bird perched on a wild cherry tree. We observed that its color was brown, brightest on the head, and thickly dotted on the breast and sides with darker brown heart-shaped spots. The throat was light in color. The bird was about eight inches in length: tail, nearly even; bill, long and brown. With a final burst of song he flew away. "What does he eat?" "What kind of nest does he build?" "What is it made of?" and "Are there eggs in it?" These were some of the questions asked about the little songster.

The class observed the following birds and a committee supplemented the field work from reference books in the library:

(a) Sparrow
(b) Gold finch
(c) Thrush
(d) Robin
(e) Crow
(f) King fisher
(g) Catbird

One group observed a nest in a thorn tree; another group found a nest in the crotch of an apple tree.

General knowledge of the birds seen was gained by the individual members of the class through the oral reports of each group.

QUESTIONS AND EXERCISES

1. What are the advantages of the school journey over teaching science in the classroom? Can you think of any disadvantages?
2. How should a school journey be organized?
3. Make a survey of your community and list all materials available to science teachers for use in connection with school journeys.
4. Select one community resource and outline a school journey according to the techniques outlined in this chapter.
5. Why should a teacher visit a place before conducting a school journey there?

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Chapter 15

FLAT PICTURES AND STEREOGRAPHS

The term "flat pictures" is used for ordinary prints, photographs, and drawings in order to differentiate them from the stereograph.

Flat pictures speak a common language. Since the time of primitive man pictorial symbols have been used to represent objects and ideas. In fact, our alphabet and language were evolved from primitive pictorial symbols.

Flat pictures arouse interest with their concrete appeal. The modern teacher frequently uses pictorial illustrations to help in clarifying the meaning of some new device or idea. However, a flat picture is a substitute for reality and in this respect may have definite limitations which the teacher should be aware of:

(1) Flat pictures have but two dimensions. They lack depth, which sometimes gives the pupil wrong initial concepts.
(2) Flat pictures are not always true in color.
(3) Flat pictures are not always true in size.

These weaknesses in flat pictures should be recognized by the teacher and if possible corrected by the use of actual objects, school journeys, exhibits, or other more realistic visual aids.

Teachers should exercise care and good judgment when selecting pictures for classroom use. Good flat pictures for teaching purposes will have the following characteristics:

(1) Have one center of interest.
(2) Be true in color.
(3) Be true in size or have some familiar object in the picture by means of which the pupil can estimate size.

Since it is difficult to obtain a large number of pictures with all these qualities, the teacher should make every effort to supplement flat pictures with other improved visual aids.

Mounting pictures. Pictorial materials such as postcards, photographs, textbook illustrations, and magazine illustrations are abundant. Flat pictures worth keeping for future lessons should be mounted, labeled, and possibly catalogued. The mounting material should be pliable enough to bend without breaking. A heavy quality of Cadmus cover paper makes very satisfactory mounting boards.

The color of the mounting paper is also important. The color of the paper should harmonize with the predominating tone of the flat picture. When in doubt about what color to use select a neutral color such as dull gray or a light coffee color.

It is desirable that some system be used in labeling, classifying, and cataloguing mounted pictures. Elaborate filing cases may be purchased, but these are not necessary. A case of shelves, a simple cabinet, or even cardboard boxes may be used for filing and storing flat pictures. Some teachers find large envelopes useful for this purpose.

Bulletin board. There should be a large permanent bulletin board in every science classroom and laboratory. Its uses are many. On it may be placed photographs, diagrams, and clippings from magazines, newspapers, and books. It may be used as a place to exhibit exceptional work done by members of the class. It is also a good place for the teacher to post assignments and notices of club meetings. Bulletin boards are inexpensive and easy to make. A serviceable bulletin board may be made by tacking a piece of plain green denim over smooth pine or a piece of Celotex. A frame around the board will make it more attractive. Bulletin boards may also be made from Compo board. If several demountable bulletin boards are desired, fasten two window sash hooks to the backs of the boards. These hooks will enable you to mount the board on the blackboard or other molding which runs along the walls of your classroom. Thus different boards may be displayed when the need arises and stored away again after they have been used.

Bear in mind the following suggestions pertaining to the care and use of a bulletin board:

(1) Promiscuous posting of pictures is not desirable. Pictures should be grouped together under unit or topic headings.
(2) Pupils should be encouraged to assume responsibility for the care and arrangement of the bulletin board.
(3) Care should be exercised in the length of time material is kept on the bulletin board. As a general rule it is desirable to remove materials from the bulletin board as soon as the topic or unit with which they were used is completed.

The stereoscope. The stereoscope is an individual optical instrument which makes surfaces appear as solids and which gives a realistic impression of depth and perspective.

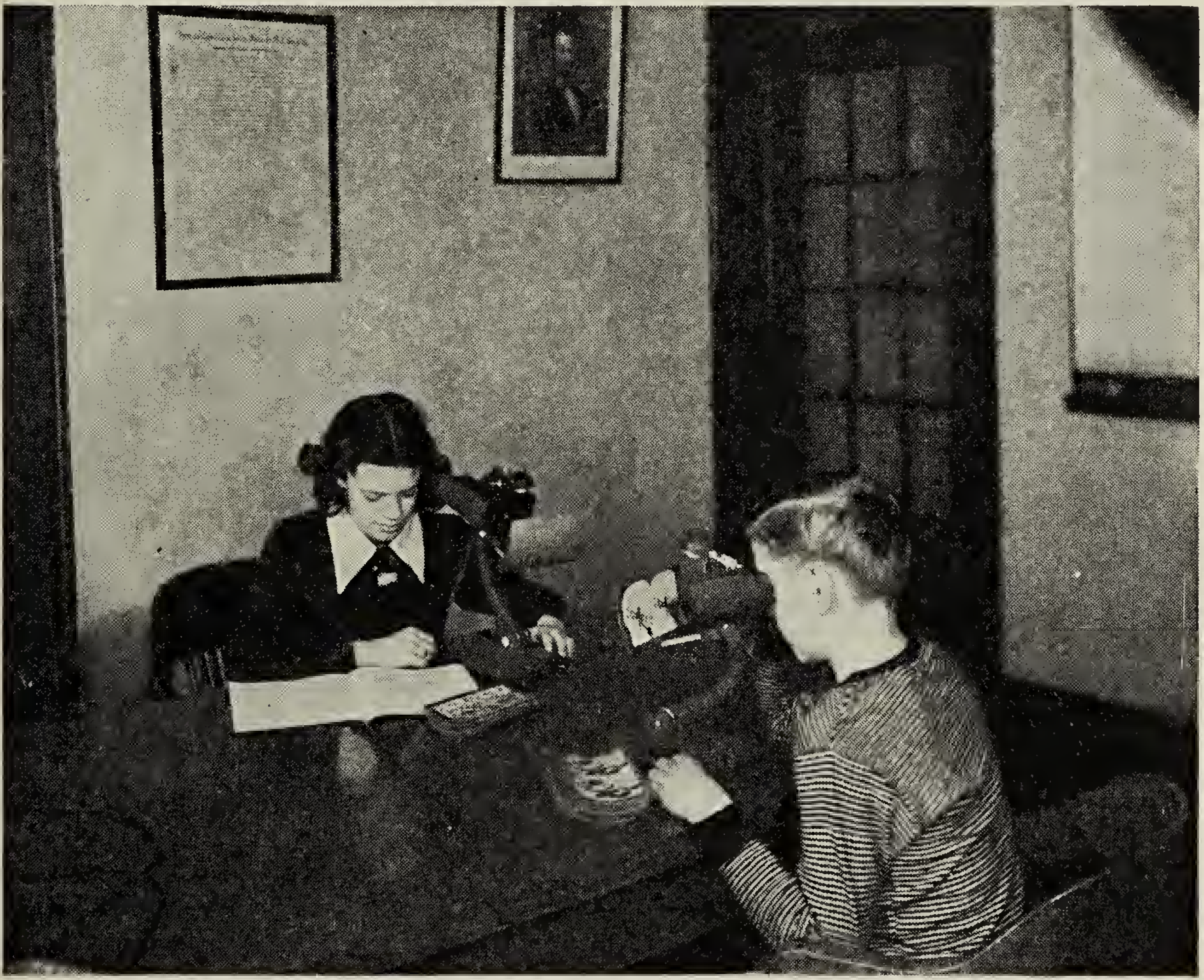

Fig. 18 Using a telebinocular. (*Keystone View Co.*)

Stereoscopes are usually of two kinds; a small, light stereoscope which can be held in the hand, and the telebinocular, a heavy mounted instrument for table use. (See Fig. 18.)

The hand stereoscope contains two lenses mounted in a frame and divided by a partition. The view with the left eye is thus separated from the view obtained with the right eye. The eyes are shielded from outside interference by a metallic hood which fits the facial contour snugly. A handle is provided for holding the stereoscope and a movable frame is fitted to the instrument for holding the stereograph.

The construction of the telebinocular is essentially the same as the construction of the small stereoscope, with the exception that the telebinocular is mounted on a heavy metallic base and is electrically illuminated. The telebinocular is usually placed on a table or desk in a convenient place in the classroom.

The stereoscope has a wide variety of uses. Several of its applications are in the fields of education, surveying, and internal or microscopic examination of objects. Impending applications lie in the direction of large scale stereoscopic projection and stereoscopic motion pictures.

The impression of reality which a student gains in the classroom through the use of the stereoscope and stereograph may awaken a latent interest in school subjects. Many schools are correlating subject matter with appropriate stereoscopic applications. Particularly in the science field the student often has difficulty in getting the correct impression needed—that of the life-like reality of third dimension.

A good example on the secondary school level is the teaching of physics. In teaching mechanics, considerable difficulty in expressing mechanical principles may be present, because of two-dimensional illustrations. If the student can see such illustrations in the third dimension, a greater appreciation of the principles of mechanics generally results.

Another example is the teaching of chemistry, where, like physics, a proper concept of the structure of the atom is needed. It is difficult to portray the structure of the atom in two dimensions, particularly on the blackboard. The use of the stereoscope, because of its third-dimensional effect, will then greatly assist in the understanding of the structure of the atom.

The stereoscope is not only useful on the secondary school level but may be applied to the college classroom or laboratory as well. The stereoscope will assist in the appreciation of wave mechanics, in the study of polarized light, and in the study of astronomy. Stereographs may be made in these subjects and are of decided value in gaining the interpretation desired.

Aside from the schoolroom, there are other applications of the stereoscope (and the telebinocular). In medicine, a special stereoscopic X-ray machine enables the surgeon to locate foreign bodies in the human body. A stereoscopic X-ray machine may greatly aid in the extraction of bullets, bits of shrapnel, and other material from the bodies of wounded persons.

Industry is benefiting from the use of the stereoscopic principle. Defects in die castings, blow holes or slag inclusions in welded joints, imperfect structural beams, hair cracks in high pressure equipment, may all be accurately located. The stereoscope is used in the examination.

The layman in the future will probably undergo a series of rigid eye tests before obtaining a driver's license. In fact, several police departments are now using the telebinocular for determining visual-acuity defects and faulty depth perception which often lead to accidents.

Pilots of airplanes must now undergo a rigid stereoscopic eye test to determine whether they have perfect binocular sense. Accurate judgment of distance and accurate judgment of the relative size of objects and color are important in making safe landings and in maneuvering airplanes. The pilot must therefore have perfect binocular vision. Misjudgment of distance often leads to serious accidents.

The stereoscopic principles are now being applied to textbooks and even to motion pictures. Textbooks are being stereographically illustrated, and students are being supplied with suitable stereoscopes for viewing the books.

Teachers desiring more information on the principles of stereoscopy may refer to such a book as that by H. C. McKay.[1]

The stereograph. The stereograph is a double photograph of an object or a scene (see Fig. 19). The photographs are taken with a stereoscopic camera which has two lenses. The two lenses are so arranged that one lens photographs the object or scene from an angle slightly to the left. The other lens photographs the object or scene from an angle slightly to the right. The two photographs are mounted side by side on the stereograph. When viewed through a stereoscope the right eye sees more of the right side of the object and the left eye sees more of the left side of the object. In the brain the two images merge together giving us an impression of depth. "By means of these two different views of an object," as Oliver Wendell Holmes, the perfector of the stereograph, so vividly put it, "the mind, as it were, feels around it and gets an idea of solidity—and then we know it to be something more than a surface." Students frequently inquire how the brain fuses two pictures into a third with depth but there is as yet no adequate explanation of this amazing phenomenon of binocular vision. Nevertheless, the illusion of a third dimension created by the stereoscope adds charm and beauty to the photographs and gives the stereograph a position of preëminence among still pictures. In fact, one wonders why more science teachers do not become aware of the amazing potentialities of this visual aid. Stereographs

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[1] McKay, H. C., *Principles of Stereoscopy,* American Photographic Publishing Co., Boston 15, Mass., 1949.

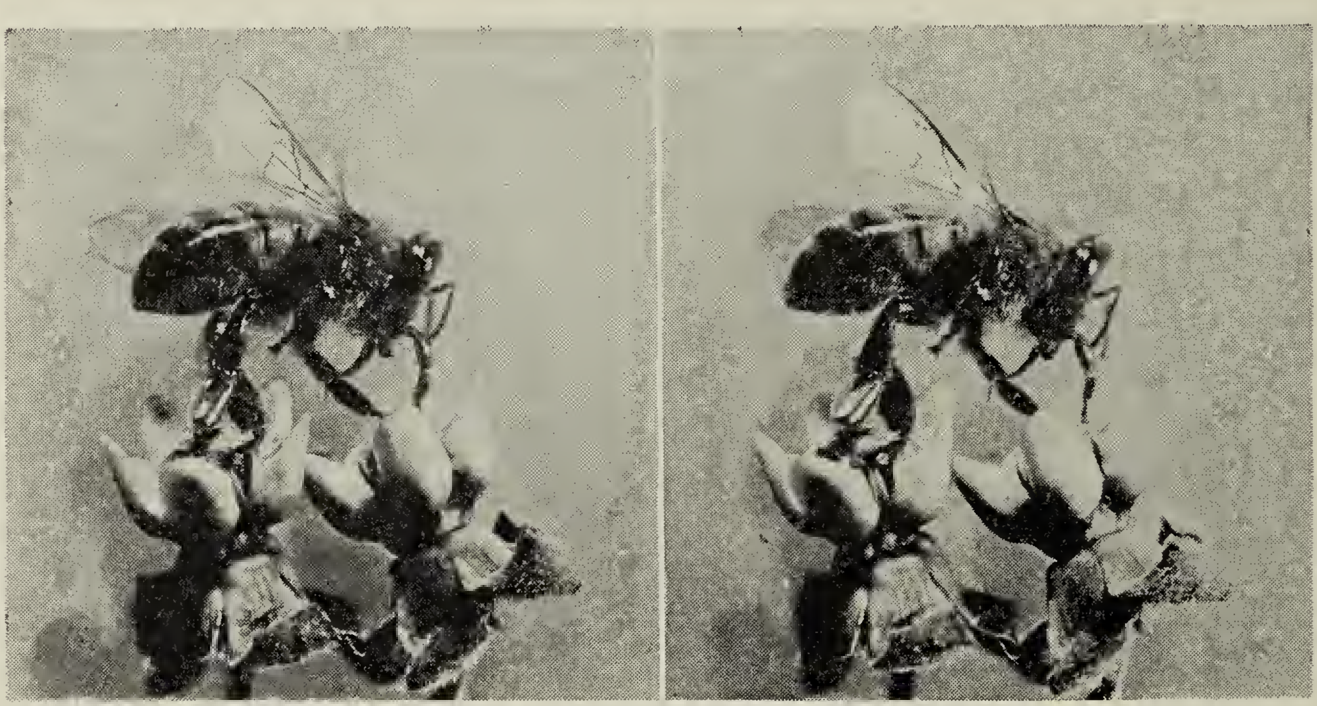

Fig. 19 A stereograph. (*Keystone View Co.*)

and slides for use in general science, biology, physics, and chemistry may be obtained from the Keystone View Company.[2]

The following suggestions are offered as guides to the proper use of the stereograph:

(1) Study only a few views in each lesson. The stereoscope is individualistic and not meant for rapid group study.
(2) Have a sufficient supply of stereoscopes on hand.
(3) Most important of all is to make sure the stereographs have a definite connection with the lesson or subject to be studied.
(4) Follow up the use of the stereoscope with adequate discussion of the material covered.
(5) Slides of the same pictures on the stereograph may be used in collaboration with the stereographs.

The educational values that can be gained through the use of the stereoscope and stereograph are as follows:

(1) The illusion of reality produced by the stereoscope and stereograph makes a profound impression on the student.
(2) Slides can be used with the stereographs as supplementary material.
(3) Stereographs aid in reference reading and library work.
(4) Installation costs are quite reasonable.
(5) Stereographs are readily adaptable to the socialized type of recitation.

The stereo-viewer. The stereo-viewer is, in reality, a modern development of the old hand-card stereoscope. It is used to view three dimensional pictures on film. Film widths may vary in size from 8 mm to 35 mm, with or without notches for moving the pictures into view. The lenses are usually achromatic, cemented doublets and focusing is possible in some. In others the film is so fixed as to be in focus when the film is in the proper position. Other viewers have inter-ocular adjustments and internal illumination, but these are not always necessary. The case is usually plastic and the whole viewer is generally not larger than an ordinary pair of opera glasses.

Films for the viewer can easily be secured as the viewer is generally made and designed for certain films. For example, there is the "Tru-Vue Stereoscope" (Tru-Vue, Inc., Rock Island, Ill.) for 35 mm safety films, and a catalog of many films obtainable for it. The "Stereo Realist Viewer" (David White Company, Milwaukee, Wisc.) is made for the special "Stereo-Realist Camera," a true stereoscopic camera. Or a "Stereo-Tach Outfit No. 101" may be obtained, which is a complete outfit for making stereo pictures with a 35 mm camera such as the Argus, Coronet Stereo, Kodak 35, Leica, Perfex and others. In this way a teacher can make a set of films for viewing any science project by the third dimensional effect.

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[2] Keystone View Company, Meadville, Penna. Other addresses: New York; Chicago.

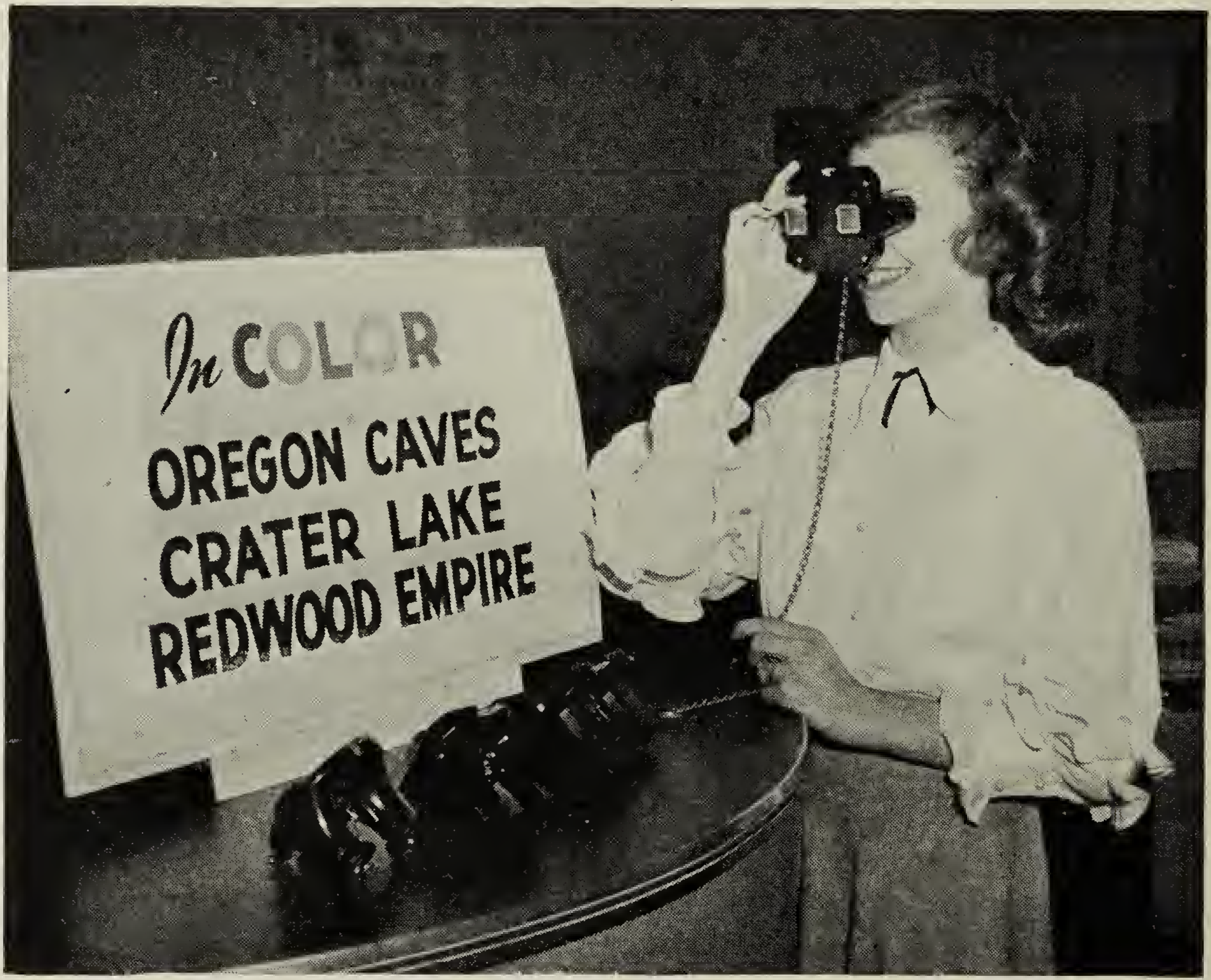

Fig. 20 Using a stereo-viewer. (*Sawyer's, Inc.*)

SOURCES OF STEREO DEVICES

Ellis & Beller, Inc., 125 La Salle St., New York 27, N. Y.
Keystone View Co., Market and Center Sts., Meadville, Pa.
Radex Stereo Co., 1328 W. Sixth St., Los Angeles 14, Calif.
Sawyer's, Inc., 735 S. W. 20th Pl., Portland 7, Ore.
Tri-Vision Sales Co., 1109 S. Fremont St., Alhambra, Calif.

True-Vue, Inc., 121 Fourth Ave., Rock Island, Ill.
White Co., 315 W. Court St., Milwaukee 3, Wisc.

QUESTIONS AND EXERCISES

1. What limitations do flat pictures sometimes have?
2. What characteristics do good flat pictures for teaching purposes have?
3. Why should every science classroom have a bulletin board?
4. How long should materials be left on a bulletin board?
5. How is the three-dimensional effect obtained in a stereoscope?
6. How may a stereoscope be used in teaching science?
7. How does a hand stereoscope differ from a telebinocular?

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Chapter 16

PHOTOGRAPHY

Photography has grown so popular that cameras are seen in many places and either black and white or color pictures are displayed daily. In fact, the camera user today is much more familiar with photographic principles than he was a decade ago. The available photographic equipment likewise has increased tremendously. Black and white photography is popular among both amateurs and professionals. Color photography is making advances but is generally more expensive and more exacting than black and white.

Color photography places many restrictions on the amateur by virtue of the present high over-all cost and the restricted degree of latitude allowed for color film. Conditions must be just right for taking the color picture, otherwise the color rendition may not be satisfactory. And after the picture is taken, the color processing and printing, even if done by the amateur, are still more costly, more precise, and more time consuming than for black and white.

Ansco Company and Eastman Kodak Company make color films which can be either processed commercially or by the amateur. For pictures taken outdoors the "Daylight Type" film is used or "Artificial Light Type" film may be used with a special conversion filter. For pictures taken indoors the "Tungsten" or "Artificial Light Type" is used or else the "Daylight Type" with special conversion filter. Ansco and Eastman Kodak color films require special processing of their own. The chemical solutions used for developing must be those required by the manufacturer, whether developing is done commercially or by the amateur. Printing of color films must also be done with special solutions and the right paper must be obtained accordingly.

Flash photography is to be recommended for color shots of children, animals, or action indoors, and in most cases except where the daylight is sufficient. Ansco Color and Eastman Kodachrome or Ektachrome can be obtained from some of the references at the end of this Chapter.

Construction and Optics of an Ordinary Camera

The fundamentals of black and white photography will be presented because the amateur should first explore fully this phase of photography before starting color work. Many principles of black and white photography lead to a fuller appreciation of color photography. It is best that the photographer get to "know" his camera and explore it's potentialities for black and white exposures before proceeding to color.

A photographic camera contains certain essential parts. The simplest type, the pinhole camera, consists chiefly of a rigid or fixed box, approximately 4 in. by 4 in. by 3 in., closed at the front except for a pinhole in the center of the face. A ground glass screen is placed at the back for viewing the image. If the screen end is held to the eye and the camera pointed at an object such as a sign or a tree, the screen will receive an inverted and reduced image of the object.

The image produced by the pinhole camera may not be a clear one because of the diffraction of the light. If a double convex lens is substituted at the pinhole, a much clearer image will be obtained. As is natural with such a lens, this image will also be inverted, but its size will be the same if the lens is at the same distance from the ground glass screen. The position at which the lens produces this sharp image is known as the focal plane.

If the screen or focusing panel is replaced by a light-sensitive film or plate, the image may then be permanently recorded. This requires a back support, the "receptacle" for holding the film or plate. This combination is called a box camera and represents in action the principles of all cameras.

Modern devices such as the shutter and the diaphragm have been added to the box camera to aid the taking of a picture by

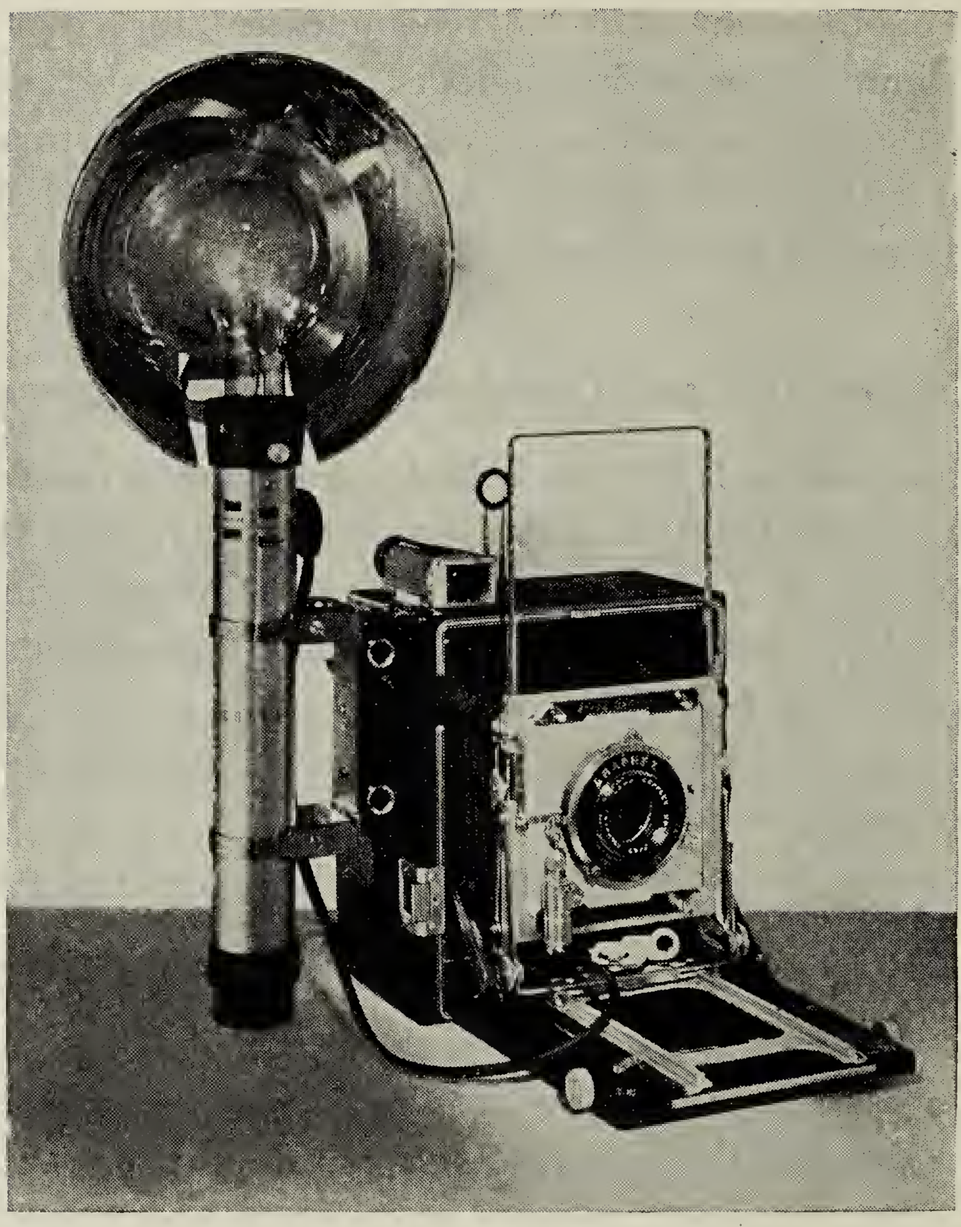

Fig. 21 A typical plate or sheet film camera. (*Graflex, Inc.*)

controlling the length of exposure, and to cut down or increase the intensity of the light striking the film.

Some cameras have focusing scales for different object distances. Nearly all of them now have view finders which locate the image for the photographer and help to produce a properly balanced picture.

Types of Cameras

The large variety of cameras available today may be classed into two large groups: the "roll film" cameras, having the film on reels or rollers at the back; and the "sheet film" cameras, using cut film, film packs or plates. Both of these groups may include rigid or folding types. Some examples of rigid "roll film" cameras are the box, twin reflex, miniature, and movie cameras. The miniature and roll cameras may also be of the folding "roll film" types. Some examples of rigid "sheet film" cameras are the reflex, box, aerial, fingerprint, and Cirkut panorama cameras. Folding "sheet film" cameras include the hand, news, or professional types such as the view, portrait and copying cameras.

Most of the cameras which a science teacher should use will be one or more of the following:

The plate or sheet film camera. In nature photography this camera has desirable advantages in focusing for close-up pictures by using the double extension bellows with longer exposure time. Cut film, film packs and plates may be used for either black and white photography or color. Flash photographs with this camera may also be taken and are of decided advantage for stopping action in nature.

A typical plate camera is shown in Fig. 21. This type of camera is essentially a folding camera with a special backing. A piece of frosted plate glass may be at the back for the photographer to view the picture, especially for focusing when single or double extension bellows are used. Or the camera may be equipped with a range-finder of either the "split-image" type or the "super-imposed" image type. After the camera is properly adjusted a cut film, filmpack or plate holder is inserted in the camera. Before taking the picture, the film or plate is made ready for exposure by the removal of a slide.

The reflex camera. The reflex camera is a very popular camera for field trips and tours where opportunities for taking scenic or subject pictures are present. The reflex camera has the big advantage of being able to sight an image which is seen in the full size of the negative and right side up.

A typical reflex camera is shown in Fig. 22.

Single lens or twin lens reflex cameras are available. In the twin lens reflex camera the viewing image is produced by a lens which is a duplicate of the one exposing the film, so that whatever is viewed is sure to be similar to the lens exposing the film.

The folding roll film camera. This camera can be folded and is a standard product. Many films and accessories are available for

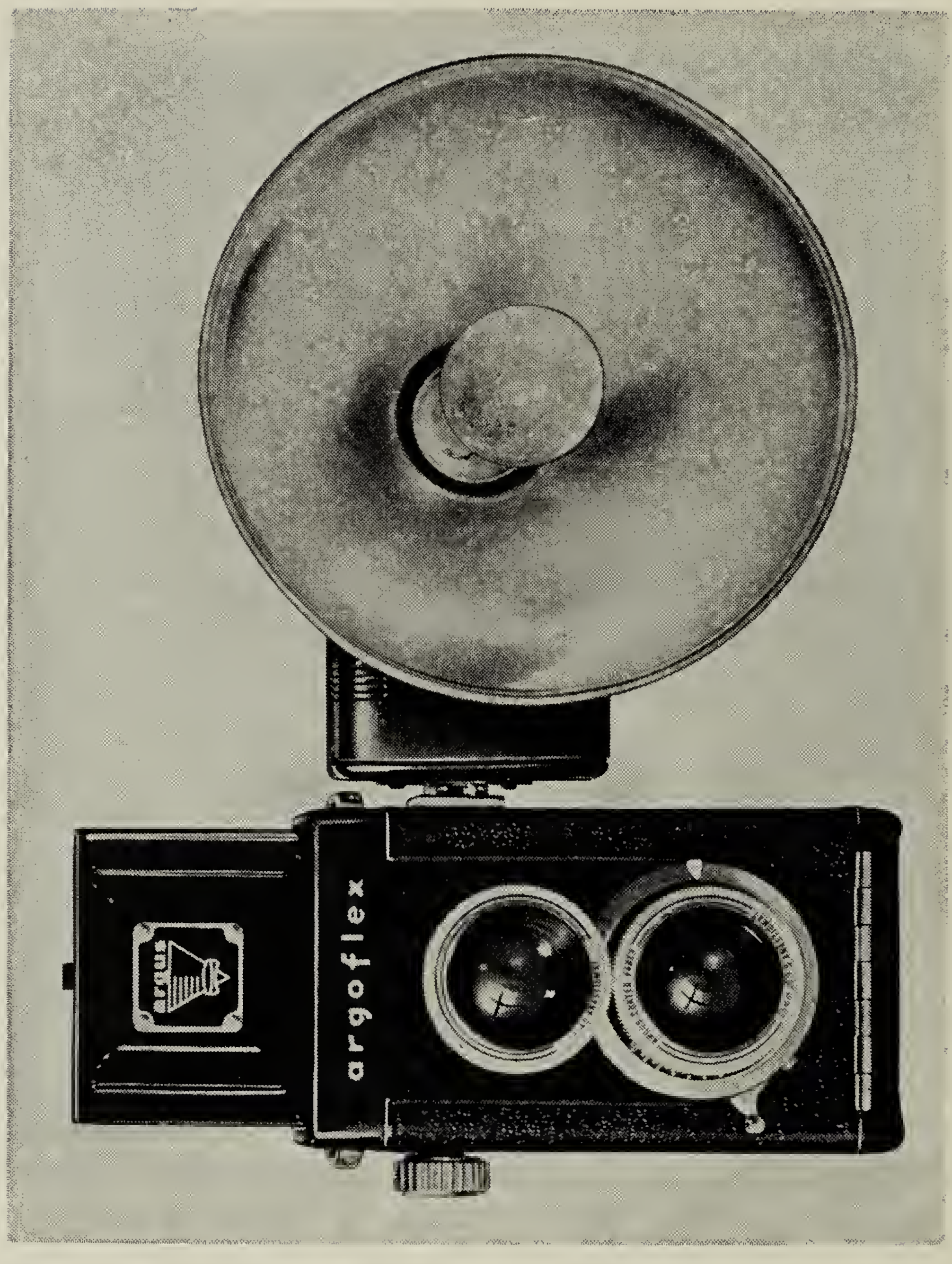

Fig. 22 A typical reflex camera. (*Argus, Inc.*)

use with it. The camera is popular for scenic, subject and group pictures. It folds to a relatively small size so that it can, in some cases, be easily carried in a pocket, small case or grip.

A typical folding roll film camera is shown in Fig. 23. A camera of this type is essentially the same as the box camera. However, it may have extension bellows that enable the user to move the lens backward or forward for focusing or folding. The back contains two rollers, one at each extremity. One roller accepts a roll of film. After each picture is taken, a knob or key is turned on the outside and the film moved for a new exposure.

Examples of folding roll film cameras are the 120 and 620

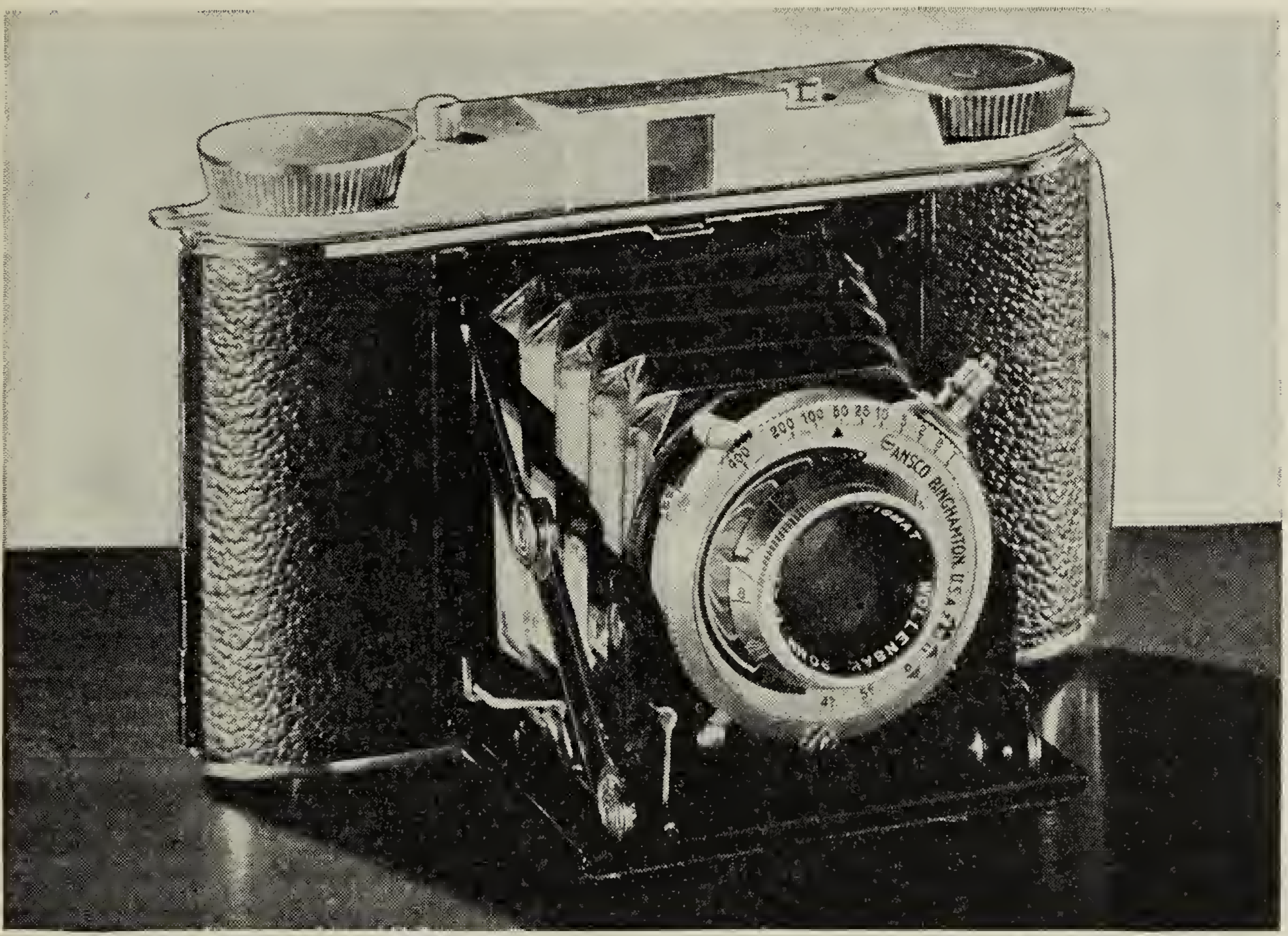

Fig. 23 A typical folding roll film camera. (*Ansco Co.*)

types. They can be loaded and unloaded in daylight and the film quickly processed.

The miniature camera. The miniature camera is very useful to the amateur, professional and newspaper cameraman since pictures can be taken under conditions of poor illumination or where flash pictures are prohibited. This makes it especially valuable for candid photography.

While the 35 mm "still film" or "film slide" camera is very popular, cameras making negatives of 2¼ in. by 3¼ in. and even smaller in size are now considered miniature cameras. Actually the ideal miniature camera makes a negative 2¼ in. by 2¼ in., because the negative is very useful for contact prints in panel shape.

A typical miniature camera is shown in Fig. 24.

The miniature camera is a *precision* instrument permitting a greater latitude in focusing. With critical exposures (usually with an exposure meter) and the right film to do the job desired, this is ideal equipment for records where numerous photographs of

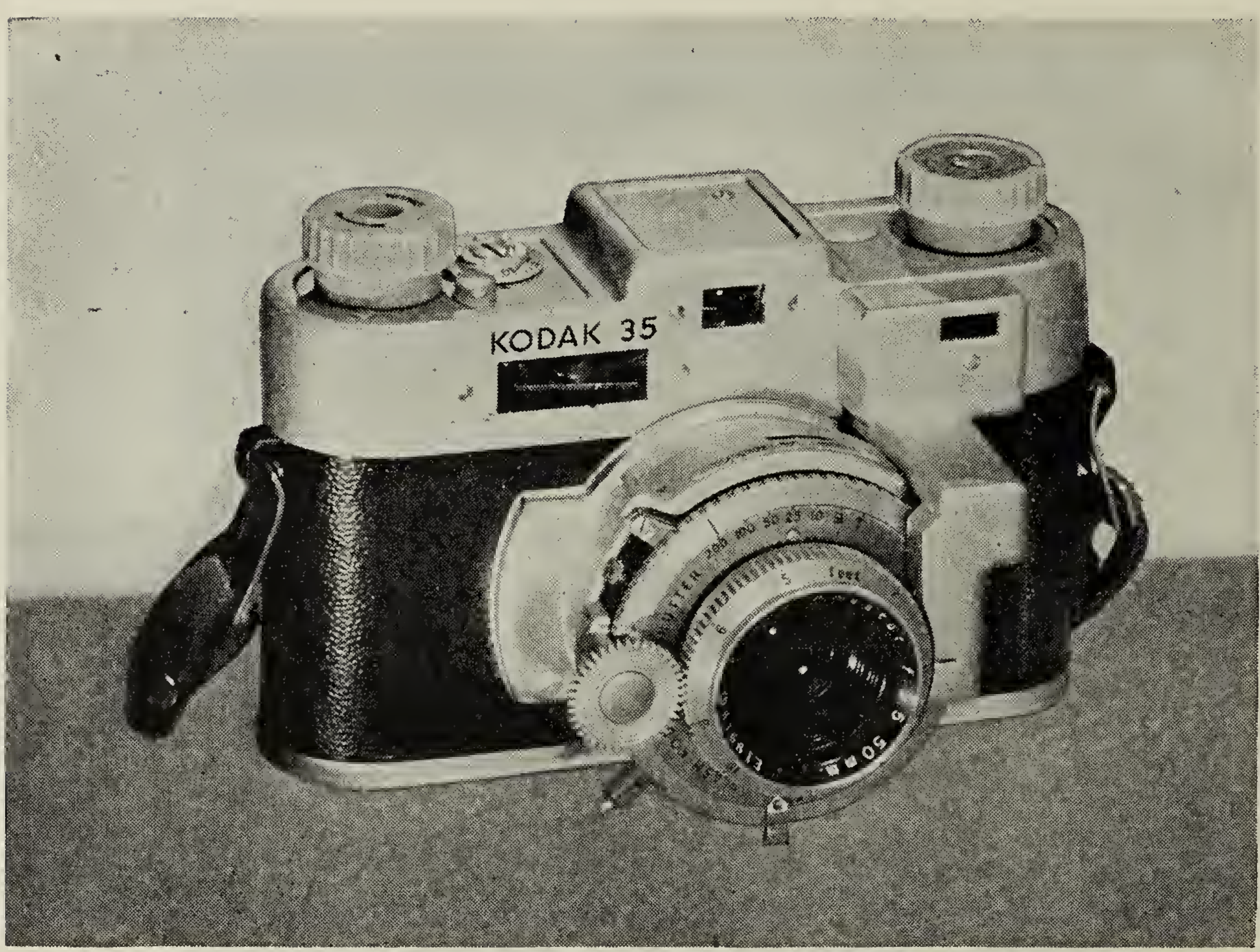

Fig. 24 A typical miniature camera. (*Eastman Kodak Co.*)

procedures are desired. For these reasons the miniature camera should supplement larger cameras.

If you own one of the so-called "35" cameras (35 mm film size) you can obtain important accessories for it to do close-up pictures (portra lenses), wide angle lens pictures, copying, enlarging, and photo-micrography. Science teachers will find such 35 mm cameras most versatile and applicable where unity of study of subject matter is needed. Color or black and white films are available for either single-frame or double-frame 35 mm cameras. These films, when made into positives, can be projected for classroom instruction.

Some examples of 35 mm miniature cameras are the Argus, Contax, Leica, Retina and Robot. The Miniature Speed Graphic makes a negative 2¼ in. by 3¼ in., as does the 620 and 120 folding roll film camera.

An application of a miniature camera to teaching safety by one of the authors is given in several magazines in the references at the end of this chapter.

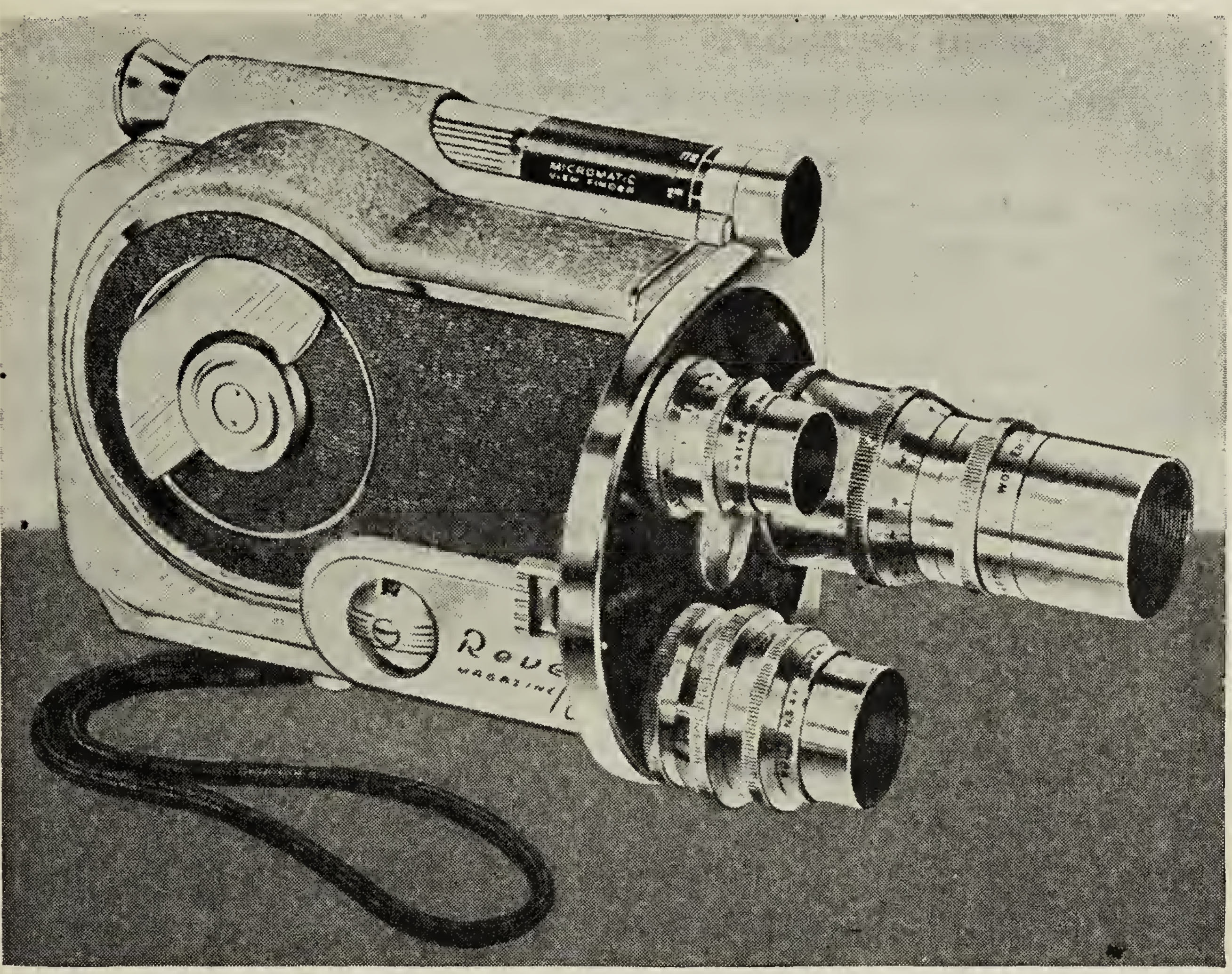

Fig. 25 A 16 mm motion picture camera. (*Revere Camera Co.*)

The motion picture camera. Two types of motion picture cameras popular with amateurs are the 8 mm and 16 mm film sizes. They are simple in operation and may be either reel loaded or magazine loaded for film lengths of 25 feet, 50 feet and 100 feet. Most of these cameras are of spring wind action and a few have an electric motor drive available. Several lenses may be used on a turret, depending on the job to be done, and special filters can be obtained for color or black and white photography.

A typical motion picture camera (16 mm) is shown in Fig. 25. While many motion picture cameras are of the silent film type, nevertheless there are cameras that will record sound and picture on the film at the same time. Even if silent pictures are taken, commentary sound may later be "dubbed in" with the aid of a recorder. Information on recorders can be obtained in Chapter 22.

Sound systems. The technical details of these cameras are too voluminous to be described here. If interested, the teacher should consult the references at the end of this Chapter.

Taking the Picture

There are several factors that require consideration when preparing to take a picture. The photographer should realise that his eye and the "eye of the camera" are not the same and that selection of the right conditions for taking the picture is most important.

Selection of the right conditions involves knowledge of light control, filters, accessories, camera lens and shutters, and sensitive emulsions. Since these subjects are so extensive, only brief descriptions of these factors can be given here. Such items as techniques or special effects depend mostly on the skill of the photographer or the amount of experience obtained by him, and are beyond the scope of this chapter.

Light control. There is little that can be done to control natural lighting for taking the desired picture outside of waiting for the proper light conditions to present themselves. The one fact to be borne in mind is that the judgment of light intensity by the human eye is not the same as that for the camera "eye" and film. If directions supplied with the camera and film are followed, many disappointments can be avoided. Of course much of this success depends on the ability of the photographer and the knowledge gained from past study or experiences.

If the natural lighting is insufficient and a picture is to be taken in black and white, flash or flood lighting may be used locally to supplement the daylight. This requires very careful attention and is not advisable without first consulting the various flash or flood photography guides. For color work indoors, with natural light coming through an opening onto the subject, much skill is required if the types of illumination are mixed.

In most cases a "light" meter or "exposure" meter is always a decided asset. The meter may be either the "extinction" type or the "photocell" type. The latter is more reliable and more expensive than the former. In the extinction type meter, the light is examined through a graduated density wedge which is adjusted until the subject or "guide number" is just visible to the eye, at which point the setting gives a value for getting the correct exposure. In the photocell type meter, the amount of light, incident on the subject or reflected from the subject, falls on a photocell. The photocell, in turn, sends a small electric current to a meter which indicates a value for calculating the proper exposure.

Artificial light can be controlled much better than can natural light because the photographer can use "auxiliary" electric bulbs, photofloods, flash bulbs, or electronic flash. Again an exposure meter is really a necessity for electric bulb or flood bulb illumination since it is fairly steady. Flash bulbs and electronic flash are synchronized with the shutter so that no light meter is needed if the directions are followed. Flash bulb ratings determine the exposures, and synchronizers open and close the shutter when the light intensity peak output of the bulb is reached.

Filters. Once the proper lighting of the subject is obtained, a lens filter may be needed. Since the eye is sensitive over the visible light range, i.e. about 3750 Angstrom units to 7000 Angstrom units, a film of the right emulsion plus a corrective filter may thus reproduce a visual scale of brilliancy. "Corrective" filters reproduce an object of their own color by photographing it as white or extremely light grey. If effects different from nature are desired, "selective" filters are used. However, an increase in exposure is needed for any filter and this "filter factor" depends on both the filter and the film emulsion with which it is used.

Filters may be made of colored gelatin cemented between glass, or of optical colored glass. The latter are more stable and durable than the gelatin kind. Filters may be either square, such as 2 in. by 2 in., or may be disc-shaped of different size diameters to fit over the camera lens in adapter rings; i.e. series V, VI or VII. A sunshade over the lens is always recommended to cut down reflections, and the filter always should fit back of the sunshade next to the lens.

There are filters for outdoor use and indoor use with black and white or color photography. They may have "Wratten" designations or "color" designations. Their spectral transmission curves may be of value in special scientific investigations. At least some instructions are supplied with each filter and, if not, reference should be made to a standard photographic manual.

The camera lens and shutter. Now that the proper lighting conditions and filter are obtained, the camera lens and shutter are most important as far as exposure is concerned. Exposure now depends on the "fastness" of the lens; this is really a function of its ability to gather in the light rays coming to it. Thus lenses are called either "slow" or "fast," and are designated in the "f" system as f1.9, f3.5, f4.5, f5.6, f6.3, f8, f11. In the "f" system, the number of a stop is obtained by dividing the focal length of the lens by the diameter of the opening. Thus, if the widest diaphragm opening is f1.9, the lens is likewise designated f1.9 and would be a "fast" lens. Lenses f6.3 and less are used for color photography or black and white. But above f6.3, i.e. f8, f11 or "slow" lenses, color photography is not advisable.

"Fast" lenses are used for stopping action, and are found on many movie cameras. "Slow" lenses, f6.3 or more, are found on some folding cameras and box cameras where "poses" are most common and where longer exposure can be made. Coated lenses keep down surface reflections and aid in color rendition. Test negatives can be made of the desired degree of sharpness over the whole picture.

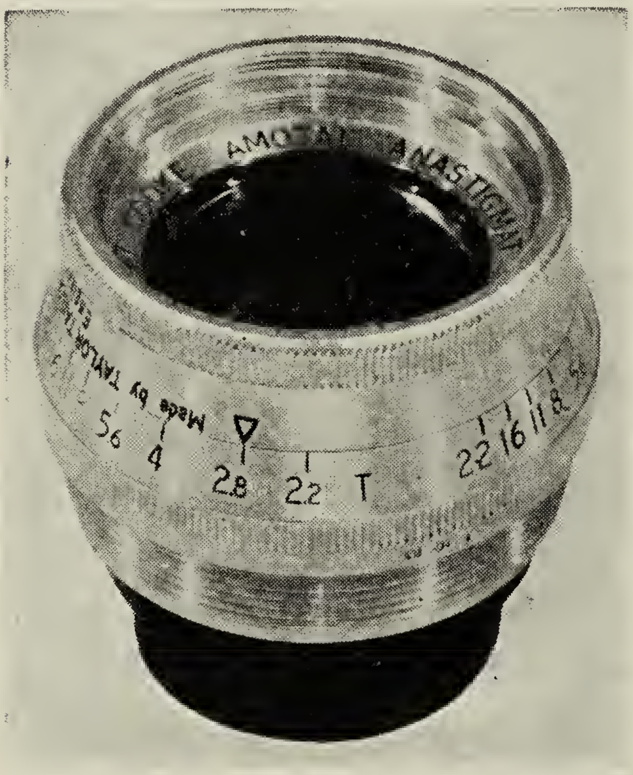

Fig. 26 A T-stop calibrated lens. (*Bell and Howell Co.*)

In the early development of photography most lenses were relatively simple with few elements and no coating. But lenses have become more complex, faster, and composed of more elements. Coating has increased the transmission of some lenses so that the f/stop system is giving place to the T-stop system, "T" meaning transmission of light.

The lens calibrations in the T-stop system are determined by comparison with free and known light passing through an aperture in which there is no glass and therefore no light loss. The T-stop equals the focal length of a lens, divided by the diameter of an open hole which transmits the same amount of light as the aperture being calibrated. Thus a T-8 designation on any lens, for example, will admit exactly the same amount of light as T-8 on any other lens calibrated in the T-stop system. A Taylor-Hobson Cooke lens calibrated in the T-stop system is shown in Fig. 26.

In choosing a lens, as a rule of thumb, the focal length should slightly exceed or equal the length of the diagonal of the film to be most often used. It should be partly corrected for color and anastigmatic with surfaces highly polished, clean and free of scratches.

Shutters for lenses are designated as "between-the-lens," or "leaf type" shutters and "focal plane" shutters. In general, between-the-lens shutters rarely go above $1/500$ sec. while focal plane shutters may give speeds of $1/1000$ sec. and over.

Shutters and diaphragms should be of a reputable make, as they usually go together with the lens, and they should be in good working condition for best results. Provision for flash synchronization is of decided value. Of course flash pictures can be taken otherwise, but when synchronizers are used the shutter is open at the proper time to receive the maximum light output of the bulb. If flash is not possible, the shutter can be opened and the room or scene "painted" with light by moving a floodbulb around.

Emulsions. Finally, in taking a picture the choice of plate or film emulsion is probably the most important factor. If the photosensitive emulsion could faithfully record all the color the eye sees, it would be wonderful. But many emulsions are "color blind," i.e. sensitive to only a certain small range of the visible spectrum and insensitive to other parts.

Emulsions are classed, therefore, by their color sensitivity, the ordinary emulsion being responsive to blue light, the orthochromatic being sensitive to the blue and green regions of the spectrum, and the panchromatic being sensitive to the blue, green and red regions. The best known emulsions are known as Verichrome and Plenachrome, both being orthochromatic emulsions.

It is surprising to note that such orthochromatic emulsions as

Verichrome and Plenachrome have such wide latitude compared to other emulsions. This is partly due to the double coating with a "slow" and "fast" emulsion. Hence the exposure tolerances for Verichrome and Plenachrome film are very much wider than for the panchromatics and color films.

Panchromatic emulsions may be of type "A" regular pan, type "B" Pan or Portrait Pan, or type "C" Hyperpan or Supersensitive Pan. The newer panchromatics are almost as sensitive to the spectral colors as the eye. Eastman Portrait Pan and Wratten Panchromatic belong in this class. There are hyperchromatic emulsions sensitive to yellow, orange and red, and include such films as Panatomic-X, Super XX Panchromatic, Superpan, Superpan Press, Super Panchro-Press, and Supersensitive. Those sensitive to the red or infra red are the Eastman Spectroscopic plates and various infra red films.

The amount of sensitivity of emulsions is a much debated question, and ratings of sensitivity are generally indicated today as A.S.A.[1] readings. The wise photographer will consider both the color sensitivity of the emulsion to be used and its sensitivity rating. For further information the reader should consult some of the references or write to various photographic companies such as Ansco, Binghamton, N. Y., or Eastman Kodak Company, Rochester, N. Y. Almost every emulsion has an anti-halation base to cut down fogging from radiations scattered by the emulsion, or for reflections from the backing.

Thus, in summary, it might be said that all the factors mentioned in taking a picture are vital for best results. Proper lighting control, selection of the right filter, setting the lens and shutter speed, together with choosing the proper emulsion, are basic. These require constant attention and should be thoroughly investigated before making each exposure.

Technique of Development

The negative. Exposure produces a "latent" image on the sensitive emulsion of the plate or film. Since the emulsion contains a light sensitive silver salt, the light-struck part of the salt is reduced to silver by the developer. In this way exposure determines the amount of silver to be deposited in the negative and this is termed its "general density."

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[1] American Standards Association.

Development is related to exposure and determines the amount of contrast. Increasing the time of development within certain limits produces a greater difference in the density of the highlights and shadows, as well as more contrast.

The maximum contrast that can be obtained by a film or plate is known as "gamma infinity" which varies slightly with the different developers, time of development, and grain size range. Process or slow-speed emulsions have high "gamma infinity" values but are slow in speed, while ultra-speed emulsions may have larger grain sizes and low "gamma infinity." Such fast supersensitive emulsions are generally used for scientific work and portraiture. A fast-speed film or plate should therefore be developed with a fine grain developer if enlarging is to be done.

Developing the film or plate. Films and plates should be removed from the camera under a particular safelight or in total darkness. The safelight, usually a Series 2, should be a deep enough red for ordinary and orthochromatic materials so that it will not cause fogging at 3 feet for ½ minute. A Series 3 (deep green) safelight can be used for some red-sensitive panchromatics. For supersensitive types of panchromatic materials it is necessary to have total darkness. The removed plate or film is then ready to be placed in the developer for the proper length of time.

The developing solution contains a reducer and a restrainer. The reducer is the agent which changes the silver bromide in the emulsion to silver, while the restrainer prevents reduction of unexposed silver grains. Metol and hydroquinone are the chemicals which act as reducers, while potassium bromide is the restrainer. Other chemicals include a sulphite as a preservative against oxidation and a carbonate to speed up the developing action.

Fine grain development of film in a developing tank is 20 per cent longer than the film developed in a tray. Ansco Microdol, a Fine Grain Formula, may be used, or Formulae 6-D; many other standard tray or tank developers may likewise be used.

Prepared developers are not economical when considerable work is to be done since their composition cannot be varied to produce special effects or to take care of local conditions. Prepared developers usually are available in three forms:

(1) Liquid—Micrograin 85, Versitol, MPG, Edwal 12 or 20, etc.
(2) Powder—MQ tubes, Dektol, Vividol, etc.
(3) Tablet—Burroughs Welcome Tancol and Rytal.

It is important that all solutions for treating the negative be kept at the same temperature, approximately 68° F., otherwise graininess or reticulation may result. If the temperature gets as high as 70° F., due to outside conditions which cannot be controlled, then tropical developers in open tanks or trays should be used. Such solutions as Ansco Tropical Developer No. 64, Formula D-61A, Eastman Tropical Developer, and Eastman Kodak Tropical Developer DK-15 may be used. Replenishers are available for some developers for use when large amounts of developing weaken the developer.

After the negative has had sufficient time in the developer it should be thoroughly washed with running water. If the negative is quite large, a "stop-bath" is advisable between developer and fixer. The acid "stop bath" tends to neutralise the surplus alkaline developer and thus lengthens the life of the fixer. It is also valuable in reducing the amount of stain caused by some developers. The fixing solution may be Eastman hypo Formula F-1 plus Formula F-1A, or chrome Alum Fixing Bath Formula F-16. The fixer removes unexposed and undeveloped silver salts and hardens the emulsion. It should not cause stains; if it does, it may need discarding. It should not be replenished.

Sometimes intensification of a negative is needed so that the negative becomes more light or dark, and so the highlights become slightly denser. Such formulas as that of Mercury Intensifier or Silver Intensifier Formula IN-5 are used. Likewise a negative may be too dense so that a permanganate reducer, persulphate reducer, or Farmer's reducer, should be used.

Many photographers like to toughen their negatives against scratches and so they use a prepared concentrated hardening solution after the final wash. Some of these are known as FHS (Fitzsimmons Hardening Solution), Claro, and Kin-O-Lux.

Developing and fixing tanks are available today that permit daylight loading and daylight development especially for 35 mm or other roll film of such sizes as 620 or 120. Others available include the Kodak Film Pack Tank and the F-R Adjustable Cut Film Pack Tank.

Technique of Printing and Enlarging

The positive or print is now made and becomes the final major phase in the photographic process. Prints are made on almost any kind of material: "blueprints" on steel, prints on paper, glass, celluloid or cloth.

Printing papers are either single weight or double weight and of three classes of emulsions:

(1) Chloride papers or slow emulsions of from 1:5 to 1:60 exposure ratio.
(2) Bromide papers or fast emulsions for enlarging, of from 1:15 to 1:100 exposure ratio.
(3) Chlorobromide papers of varying speeds but quite usable for enlarging.

Some surfaces of printing paper emulsions are designated as follows: glossy, semi-matte, velvet, smooth matte, slightly rough, rough lustre, silk, linen, canvas, tissue, and parchment. Contrasts in papers range from soft to medium or to hard, the zero grade being for lowest contrast negatives, and grade 1 to 6 for negatives of increasing contrast.

Invariably printing is done by contact or by projection (enlarging). Contact printers are available and many fine enlargers are also on the market. But in most cases a light and filter are needed such as:

Series OA—for bromide papers, lantern slides, process films and chlorobromide papers.
Series 0—for bromide papers and lantern slides.
Series 00—for Apex, Velox, Contact printing on chloride papers. Not for bromide papers.

Printing solutions, like the developing solutions, should be maintained at a uniform temperature of 65° F. to 70° F.

The printing formulas are mostly of the popular MQ kind, but generally should be the one recommended by the manufacturer of the paper. Some photographers make up their own solutions from the Eastman D-72 Formula or the Wellington Amidol Formula. There is a Standard Solution that can be made for all papers.

Again the print should be washed and placed in a stop bath before fixing. This is particularly important during warm weather. Fixing is usually carried out with the regular hypo solution or a fixing solution specially made for the paper or recommended by the manufacturer.

For anyone on a trip who wishes to develop films or paper on the spot, the Eastman "Tri-Chem Pack" is now available. It is small enough to be put in a pocket, yet contains enough chemicals for small amounts of developing or printing.

Copying. Often it is necessary to make a photographic copy of some pictures, drawings, printed matter, diagrams, charts and even other photographs.

The best way to copy work of the kind given previously is to use a view camera or commercial camera with an easel at one end of the camera holder. The axis alignment of the camera and easel must be parallel and must coincide for the best results.

The choice of the emulsion or filter to be used depends on what is being photographed. For example: blue prints or sepia toned prints need a pan film or plate with a type "A" filter. A pure black and white line cut needs a process emulsion. Slow or process panchromatic emulsions are best for copying old faded or yellow-brown (aged) photographs. If pages of a book or magazine are to be copied it is best to place a piece of black paper under the sheet to prevent the reproduction of the "under-printed" page, and then develop the film for extreme contrast.

The photographer can use filters to good advantage for most copy work if it is remembered that the color of the filter allows the same color light as white to get through and be photographed. If it is desired to photograph anything in black, the complimentary color filter should be used. By a judicious selection of filters it thus may be possible to "screen out" certain portions of the material to be copied. This might be exemplified by making a copy of a red-pencil corrected exam paper, in which case a red filter would "kill" the red pencil markings by photographing them as white on the paper.

Projection printing (enlarging). In this process, the negative or parts of the negative are projected onto the printing paper. In fact, the print can be smaller than the original negative or it may be made larger as desired. Most of what has been described previously for contact prints applies here with some modifications or additions.

The horizontal-type enlargers usually contain a separate light housing and separate easel, most of which is now obsolete since the light is contained in the enlarger. The vertical type has become more popular because its position is convenient for throwing the enlarged picture down on the work table where it is easily viewed.

Vertical enlargers may have automatic focus, i.e. as the enlarger is moved down, the lens is automatically pulled out at a rate which keeps the picture in focus. Exposure time can be obtained with the use of a photoelectric cell-enlarging meter now available and known as a "Printometer."

Enlarging papers of varying speeds may be used, such as bromide (fast) or chlorobromide (medium), both with surfaces similar to those for contact prints. Some examples are: Ansco "Brovira," Defender "Velour Black," Eastman "Kodabromide," and Haloid "Industro." A safelight series OA should be used during enlarging.

Techniques such as "dodging" are varied, a simple mask being used or waved over the area of the enlargement to be given less exposure. Likwise "flashing" techniques are used to darken some areas of an enlargement particularly around the margin or edges. If shaded or faded off areas are desired on the enlarging, a "vignetting" technique is employed. Fuller information on this can be obtained from the references.

The school darkroom laboratory. The darkroom is really a laboratory of its own so that there are some factors that should be considered when making one.

Perhaps the location should be given the first consideration. This should mean its nearness to a water supply, particularly running water free of dirt and rust. On the other hand, a certain amount of dryness and some way of controlling the temperature during outdoor seasonal changes should be present.

The darkroom itself should certainly be light-tight or light-proof with adequate ventilation at all times. A double door entrance or a maze type of open entrance are sometimes used. The furniture or "hardware" inside may vary, but tables, shelves and other pieces of apparatus as well as "stock" should be readily accessible. In some cases, attics, cellars or vacant bathrooms have been converted successfully but do not always answer the purpose, particularly if the photographic work gets detailed or too voluminous.

Some pieces of equipment that will make the "life and lot" of the photographer easier are as follows:

(1) Sufficient hard rubber, porcelain or enamelled steel trays.
(2) A few small open tanks for standard size films or plates, such as 5 in. by 7 in., with capacities of ½ gallon or even 1 gallon.
(3) A good timer that will give an audible signal in the dark, possibly with weak luminous hands and numerals and a particularly large sweep-second hand.
(4) Hangers for film or supports for plates.
(5) Thermometers showing some temperature above and below 68° F.
(6) Safelight lamp with filters sufficient for plates, films and papers to be handled.
(7) Waste disposal facilities such as cans, baskets or crocks.
(8) Proper scales and weights if developing or fixing solutions are to be made. The ranges of these scales and weights are determined by the quantities of developer or fixer to be made.

SOURCES OF PHOTOGRAPHIC CATALOGS

Central Camera Co., *Central's Photographic Almanac,* 230 S. Wabash Ave., Chicago 4, Ill.

Dowling's, Inc., *Dowling's Catalog.* 570 Fifth Ave., New York 19, N. Y.

Fotoshop, *Photography Bulletin,* 18 E. 42nd St., New York 17, N. Y.

Mendelsohn Speedgun Co., Inc., *1948 Catalog,* Dept. 112 Q, 457–461 Bloomfield Ave., Bloomfield, N. J.

Peerless Camera Stores, Inc., *1948 Catalog,* 138 E. 44th St., New York 17, N. Y.

Research Information Service, *Optics and Photography Bulletin No. 16,* 509 Fifth Ave., New York 17, N. Y.

Tikern Corporation, Tikern's *Film and Filter Reference Chart,* 405—44th St., Brooklyn 20, N. Y.

SOURCES OF PHOTOGRAPHIC EQUIPMENT

Box, Reflex, Roll Film and Miniature Cameras

Ansco Corporation, Binghamton, N. Y.
Argus Inc., Fourth and Williams St., Ann Arbor, Mich.
Baco Accessories, 5338 Hollywood Blvd., Hollywood 37, Calif.
Bosley Corporation of America, 118 E. 25th St., New York, N. Y.
Brand Camera Co., 500 W. Washington Blvd., Los Angeles 15, Calif.
Burke and James Co. Inc., 321 S. Wabash Ave., Chicago, Ill.
Burleigh Brooks, 120 W. 42nd St., New York 18, N. Y.
Busch Precision Camera Corp., 411 S. Sagamon St., Chicago 4, Ill.
Ciro, Inc., 425 S. Sandusky, Delaware, Ohio.
Clarus Camera Mfg. Co., 1554 Nicollet Ave., Minneapolis, Minn.
Craftex Products Corp., 1307 N. La Brea Blvd., Hollywood 28, Calif.
Curtis Laboratories Inc., 2718 Griffith Park Blvd., Los Angeles 27, Calif.
Dowling's Inc., 570 Fifth Avenue, New York, N. Y.
Eastman Kodak Co., 343 State St., Rochester, N. Y.
General Photo Supply Co., 136 Charles St., Boston, Mass.
Graflex Inc., 154 Clarrisa St., Rochester 8, N. Y.
Kalart Co., 114 Manhattan St., Stamford, Conn.
Leitz, Inc., 304 Hudson St., New York, N. Y.
Pho-Tak Corp., 21 N. Loomis St., Chicago, Ill.
Sears Roebuck Co., 925 S. Homan Ave., Chicago, Ill.
Seminar Electric Products, 56 River Rd., Beverly, Mass.
Spencer Co., 71 W. Lake St., Chicago 6, Ill.
Universal Camera Corp., 28 W. 23rd St., New York, N. Y.
Whitehouse Products Co., 362 Furman St., Brooklyn 2, N. Y.
Wm. R. Whittaker Co., Ltd., 915 N. Citrus Ave., Hollywood 38, Calif.
Willoughby's Inc., 110 W. 32nd St., New York 1, N. Y.
Carl Zeiss, Inc., 485 Fifth Ave., New York, N. Y.
Zenith Camera Corp., 709 W. Randolph St., Chicago, Ill.

Motion Picture Cameras (8 mm and 16 mm.)

American Bolex Co., 521 Fifth Ave., New York, N. Y.
Associated Photo Products, 20 E. 42nd St., New York, N. Y.
Bell and Howell, 7100 McCormick Rd., Chicago 45, Ill.

Berndt-Bach, Inc., 7377 Beverly Blvd., Los Angeles, Calif.
Briskin Camera Corp., 2103 Colorado Ave., Santa Monica, Calif.
Camera Corporation of America, 844 W. Adams St., Chicago, Ill.
Cincinnati Clock and Instrument Co., 1113 York St., Cincinnati 14, Ohio
Demournay-Budd, Inc., 475 Grand Concourse, New York, N. Y.
Eastman Kodak Co., 343 State St., Rochester, N. Y.
Excel Movie Products Inc., 4232 Drummond Pl., Chicago 39, Ill.
Franklin Photographic Industries, 223 W. Erie St., Chicago 10, Ill.
Glore Industries, 29 S. Desplaines St., Chicago, Ill.
Keystone Mfg. Co., 151 Hallett St., Dorchester P. O., Boston, Mass.
Levine & Sons Co., 55 Bromfield St., Boston 8, Mass.
L. A. Maurer, 37–01 31st St., Long Island City, N. Y.
Revere Camera Co., 320 E. 21st St., Chicago 16, Ill.
Universal Camera Corp., 28 W. 23rd St., New York, N. Y.
Victor Animatograph Corp., Third & Ripley, Davenport, Iowa.

Enlargers

A. P. Products, Norwood Ave., Deal, N. J.
American Gage & Mfg. Co., 125 Bayard St., Dayton 1, Ohio
American Photo Laboratories, 28 N. Loomis St., Chicago 7, Ill.
Austin Machine & Electric Co., 19 Syms St., Hartford, Conn.
Baco Accessories Co., 5338 Hollywood Blvd., Hollywood 37, Calif.
Cleveland Instrument Service Co., Inc., 4376 W. 227th St., Cleveland 16, Ohio
Compco Corporation, 2251 W. St. Paul Ave., Chicago 47, Ill.
Consolidated Instrument Parts Co., 23 E. 26th St., New York 14, N. Y.
Curtis Laboratories Inc., 2718 Griffith Park Blvd., Los Angeles 27, Calif.
DeJur Amsco Corp., 45-33 Northern Blvd., Long Island City, N. Y.
Eastern Photo Co., Inc., 283 Congress St., Boston 10, Mass.
Eastman Kodak Co., 343 State St., Rochester, N. Y.
Elwood Pattern Works Inc., 125 N. East St., Indianapolis 4, Ind.
Engineered Products Co., 2307 Colerain Ave., Cincinnati 14, Ohio
Federal Mfg. & Engineering Corp., 211 Steuben St., Brooklyn 5, N. Y.
Laminex Engineering, P. O. Box 1004, Akron, Ohio
Leitz, Inc., 304 Hudson St., New York, N. Y.
Merritt Products, Inc., 17 Pearl St., Springfield, Mass.
Simmon Brothers, 37–06 36th St., Long Island City, N. Y.
SunRay Photo Co., 295 Lafayette St., New York 12, N. Y.

Exposure Meters

Adair & Rhamstine, 301 Beaubien St., Detroit 2, Mich.
American Bolex Co., 521 Fifth Ave., New York, N. Y.
Amerline, Inc., 1753 N. Honore St., Chicago 22, Ill.
Burleigh Brooks Co., 120 W. 42nd St., New York 18, N. Y.
DeJur Amsco Corp., 45–33 Northern Blvd., Long Island City, N. Y.

Eastman Kodak Co., 343 State St., Rochester, N. Y.
General Electric Co., Lamp. Dept., Nela Park, Cleveland, Ohio
G-M Laboratories, Inc., 4262 N. Knox St., Chicago 4, Ill.
Grover Photo Products, 2753 E. Rable Dr., Los Angeles 36, Calif.
P. S. Martin, 235 Commonwealth Ave., Boston 16, Mass.
Mimosa American Corp., 207 E. 84th St., New York 28, N. Y.
Morgan Camera Shop, 6262 Sunset Blvd., Hollywood 28, Calif.
Photo Equipment Corp. of America, 4001 Garfield Ave. S., Minneapolis, Minn.
Photovolt Corp., 95 Madison Ave., New York 16, N. Y.
Sears, Roebuck and Co., 925 S. Homan Ave., Chicago, Ill.
Warren-New York Inc., 3310 34th Ave., Long Island City, 1, N. Y.
Weston Electric Instrument Corp., 614 Freylinghuysen Ave., Newark 5, N. J.
Willoughby's Inc., 110 W. 32nd St., New York 1, N. Y.

Films (8 mm, 16 mm, 35 mm, Sheet, Roll, Spool, Cartridge)

Anken Co., Newton, N. J.
Ansco Corporation, Binghamton, N. Y.
Dassonville Ltd., Newton, N. J.
Eastman Kodak Co., 343 State St., Rochester, N. Y.
General Photo Supply, 136 Charles St., Boston, Mass.
Gevaert Co. of America, Williamstown, Mass.
Kin-O-Lux, Inc., 105 W. 40th St., New York 18, N. Y.
Kryptar Corp., 38 Scio St., Rochester 3, N. Y.
Solar Cine Products Inc., 4247 S. Kedzie Ave., Chicago, Ill.
Weimet Co., 514 W. 57th St., New York 19, N. Y.

Flashbulbs

General Electric Co., Lamp Division, Nela Park, Cleveland, Ohio
Sylvania Electric Products, 500 Fifth Ave., New York 18, N. Y.
Westinghouse Electric & Mfg. Co., Lamp Division, Bloomfield, N. J.

Lenses

Alco Photo Supply Corp., (Dist.: Dallmeyer), 17 W. 47th St., New York 17, N. Y.
Bausch & Lomb Optical Co. (Also Dist.: Taylor-Hobson), 635 S. Paul St., Rochester, N. Y.
Bell & Howell Co., 7100 McCormick Rd., Chicago 45, Ill.
Bolsey Corporation of America, 118 E. 25th St., New York, N. Y.
Eastman Kodak Co., 343 State St., Rochester, N. Y.
Elgeet Manufacturing Co., 65 Atlantic Ave., Rochester, N. Y.
Goerz American Optical Co., 317 E. 34th St., New York 16, N. Y.
Graflex, Inc., 154 Clarrisa St., Rochester 8, N. Y.
Ilex Optical Co., 690 Portland Ave., Rochester 5, N. Y.

Leitz, Inc., 304 Hudson St., New York, N. Y.
Wollensak Optical Co., 850 Hudson Ave., Rochester, N. Y.
Zeiss, Inc., 485 Fifth Ave., New York, N. Y.

Prepared Developers

Ace Photo Laboratories, 318 W. Washington St., Chicago 6, Ill.
Alburger Research Products Co., 7354 Santa Monica Blvd. Los Angeles 46, Calif.
Ansco Corporation, Binghamton, N. Y.
Eastman Kodak Co., 343 State St., Rochester, N. Y.
Edwal Laboratories, 732 S. Federal St., Chicago 5, Ill.
F R Corporation, 951 Brook Ave., New York 56, N. Y.
Hollywood Photo Supply Co., 313 Taft Bldg., Hollywood 28, Calif.
Mallinckrodt Chemical Works, Second & Mallinckrodt, St. Louis 7, Mo.

Processing Tanks

American Hard Rubber Co., 11 Mercer St., New York 13, N. Y.
Baco Accessories Co., 5338 Hollywood Blvd., Hollywood 37, Calif.
Burke & James, 321 S. Wabash Ave., Chicago, Ill.
Burleigh Brooks Co., 120 W. 42nd St., New York 18, N. Y.
Eastman Kodak Co., 343 State St., Rochester, N. Y.
Ebe Mfg. Co., 818 Swede St., Norristown, Pa.
Fedco Products, 37 Murray St., New York 7, N. Y.
F R Corporation, 951 Brook Ave., New York 56, N. Y.
Morse Instrument Co., 21 Clinton St., Hudson, Ohio
Prime Photo Products Inc., 10909 Magnolia Blvd., North Hollywood, Calif.
Sears, Roebuck and Co., 952 S. Homan Ave., Chicago, Ill.
Willoughby's Inc., 110 W. 32nd St., New York 1, N. Y.
Windman Brothers, 3325 Union Pacific Ave., Los Angeles 23, Calif.
Wolff Mfg. Co., 3218 Olive St., St. Louis 3, Mo.

QUESTIONS AND EXERCISES

1. What factors should be considered when choosing a lens for a camera?
2. How does a telephoto lens differ from a wide-angle lens?
3. Explain the function of the rising-front, double extension bellows, and swing-back features on some cameras.
4. List the accessories available for a type "thirty-five" camera for copying, close-up work and photomicrography.
5. What are five general chemicals used in developers? Give the function of each.
6. When is intensification of the negative most useful?
7. What is the purpose of a "stop bath"?
8. List some general properties of films and plates as to (a) Speed, (b)

Latitude, (c) Fineness of grain, (d) Halation, (e) Contrast, (f) Color sensitiveness.

9. Contrast the following theories of latent image formation: (a) Subhalide, (b) Molecular Strain, (c) Photoelectric, (d) Sensitivity Speck, (e) Sensitive Sulphide Speck.
10. What factors influence the contrast in the final print?
11. How is "dodging" accomplished?
12. How does color photography differ from black and white photography?
13. What is meant by "light control"?
14. How are lenses and shutter speeds rated?
15. Explain the meaning of "no equipment is better than the care and attention it is given."

PROJECTS

1. Develop your picture-taking techniques by carrying out the following as photographic "assignments":
    - (a) *Action shot* of a moving person or animal in natural habitat. Try odd angle positioning of camera.
    - (b) *Feature shot* of a major event such as motorboat race or model airplane contest. Put people in this picture.
    - (c) *Table-top photo* of such a hobby as model trains, handicraft articles, biological specimens, or rock collections. Use only one type of lighting for indoor picture.
    - (d) *Photocopy* of a printed page, drawing, advertisement or sign. The camera should focus to seven feet or less for close-ups.
    - (e) *Outdoor photo* of a class field trip, flowers, birds, landscape, woodland scene, farm, mountain, or city park. Stop down the camera for depth and contrast.
2. Set up your plans for conducting the following classroom activities:
    - (a) *Pinhole camera contest* in which actual construction and operation of the camera is performed.
    - (b) *Amateur news contest* in which pictures of some "camera sleuthing" can be taken. Foot prints, tire tread marks, or fingerprints are suitable. Add a subsequent scientific story behind the picture.
    - (c) *Still-life Contest* in which any camera, any film or any accessory can be used.
    - (d) *Infrared pictures* requiring special film, lights and techniques for advanced science students.
3. Conduct a catalog or handbook survey of each of the following:
    - (a) Low cost cameras and important accessories.
    - (b) Film types and speeds.
    - (c) Light control.
    - (d) Prepared or packaged chemicals for development and fixation.

(e) Darkroom or daylight processing equipment.
(f) Lay-outs for albums, records, files.

4. Outline your plans for a classroom excursion to photograph some of the following:

Outdoors
Campfires
Circuses
Flower show
Summer theater
Airport
Winter sports
Farms
Boat cruises

Indoors
Factories
Theaters
Broadcasting station
Indoor sports
Dramatics
School activities
Photographic studies

5. Make a list of the ways that pictures can be taken to assist in the following civic enterprises:
   (a) Traffic problems
   (b) Parking hazards
   (c) Hospital expansion
   (d) Street construction
   (e) Public transportation
   (f) Sewage disposal
   (g) Juvenile delinquency
   (h) Housing conditions
6. Write a short discussion on the value of keeping school photographic equipment and materials both in good order and in good condition. List ways of protecting equipment and supplies from damage by heat and moisture.

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"Photography of Some Insects"
"Testing Shutters"
"Should I Go on Field Trips?"

Ansco, Binghamton, New York. Write for listing of publications including:
Ansco Color Film
Ansco Photographic Materials and Equipment for Professional Use
Ansco Photographic Papers
Better Photography Made Easy

Choosing Film for Your Camera
Color Photography Made Easy
Developing and Printing Made Easy
Planning a Camera Club
Processing Ansco Color Sheet Film
Tec-Tips

Argus, Inc., *Optical Glass Filters,* Ann Arbor, Mich.

Bell and Howell Company, *How to Make Movies in Color,* New York 20, N. Y.

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Camera Craft Publishing Co., *Pictorial Lighting,* 376 Sutter St. San Francisco 8, Calif.

Dimitri, I., *Tips on Better Color Pictures,* General Electric Co., Apparatus Department, Schenectady, N. Y.

Eastman Kodak Company, Rochester 4, New York. Write for listing of publications including:

A Brief Comparison of Photographic Instructional Aids
An Introduction to Color Copying
Eastman High Speed Camera Type III
Ektachrome and Kodachrome Professional Films
Filters and Pola Screens
Fundamentals of Photography Theory
Hints for Effective Slide Film Projection
How to Make Good Movies
How to Make Good Pictures
Kodachrome and Kodacolor Films
Kodaguides
Kodachrome and Ektachrome Exposure in Photomicrography
Kodak ABC Photo-Lab Outfit
Kodak Darkroom Equipment for Developing and Printing
Kodak Chemical Preparations
Kodak Enlarging Data Guide
Kodak Films
Kodak Lenses, Rangefinders, and Shutters
Kodak Material for Aerial Photography
Kodak Materials for Spectrum Analysis
Kodak Photographic Chemical Preparations
Kodak Photographic Notebook
Kodak Reference Handbook
Infrared and Ultraviolet Photography
Make Every Exposure Count
Photoelastic Stress Analysis
Photography by Infrared

Photography in Law Enforcement
Photomicrography
Pictures from the Air with Your Camera
Picture Taking Indoors (with Still Cameras)
Portra Lenses and a Technique for Extreme Close-ups
Processing and Formulas
Selected Indexes and Sources of Photographic Visual Aids
Selected References on Photographic Visual Aids
Short Cuts to Better Kodachrome Pictures
Slides
Snapshots Exposed
Stains on Negatives and Prints
This is Photography
Wintertime Picture Taking
Wratten Light Filters

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Chapter 17

OBJECTS, SPECIMENS, AND MODELS

A good science teacher makes provision for the pupil to see and handle materials at the right time. Effective teaching requires the choosing of the right details and the seizing of the psychological moment to make these materials stand out and serve in the process of instruction. Effective teaching stimulates a spirit of inquiry and industry in pupils and arouses in them a desire to solve problems and to achieve results.

Objects, specimens, and models offer exceptional opportunities to the resourceful science teacher. In fact, it is very doubtful whether effective science teaching can be achieved without a liberal use of these visual aids.

Objects. An object is the thing itself—for example, a bird, a frog, a grasshopper, a flower, a barometer, and the many other things which are brought into the science classroom and laboratory for study.

Objects are ideal visual aids. They are the things themselves; they are reality and not a substitute for reality. Objects are preferred in science teaching whenever it is possible to obtain them, because they put the pupil in direct contact with actual things and relationships. They provide the means for establishing correct initial concepts in the minds of the pupils.

Specimens. A specimen is a sample or a part of an object—for example, a piece of coal, a piece of marble, the skin of a bird, a leaf, or a piece of mineral. Depending upon how it is used in teaching, a thing may be an object or a specimen. An actual monarch butterfly if it were used by a biology teacher to represent all butterflies would be a specimen. However, if the monarch butterfly were used to study only the characteristics of the monarch butterfly it should then be classified as an object.

Specimens are excellent visual aids for science teaching but they are not quite as valuable as objects. Since they are only a sample or a part of an object they cannot stimulate as complete a sensory experience as do objects.

Models. A model is a replica of something. It may be a representation in miniature—for example, a small model of the working parts of an automobile—or it may be a representation in enlargement, such as a model of a paramecium or a model of a hydra.

Models are very helpful to science teachers, but they also have their limitations. Models generally are not true in size or color. If a biology teacher employs a model of a paramecium, incorrect concepts may be formed in the minds of the pupils about the paramecium unless provision is made in some way to overcome the psychological limitations of the model.

Museums. One of the chief aims of science teaching is to make children intimately acquainted with the nature of the world in which they live, to teach them to understand and appreciate the interrelationship between man and his environment. Children cannot gain such appreciation and understanding of their surroundings by merely reading about things; it must come through observation and handling them.

Observing objects and phenomena in their natural setting is the ideal way to gain knowledge. However, with our present system of mass education this is not always possible or feasible. It becomes exceedingly important, then, that we bring the outside world into the classroom and laboratory through exhibits and other concrete representations of things.

The science department of every school should begin a museum. There is a wealth of material within the reach of nearly every school. The natural instinct for collecting and hoarding which many children seem to have should be utilized for building up the museum as well as for motivating and vitalizing the subject matter of science courses.

The following list of topics is indicative of the great variety of specimens and objects from our world of living things which may be

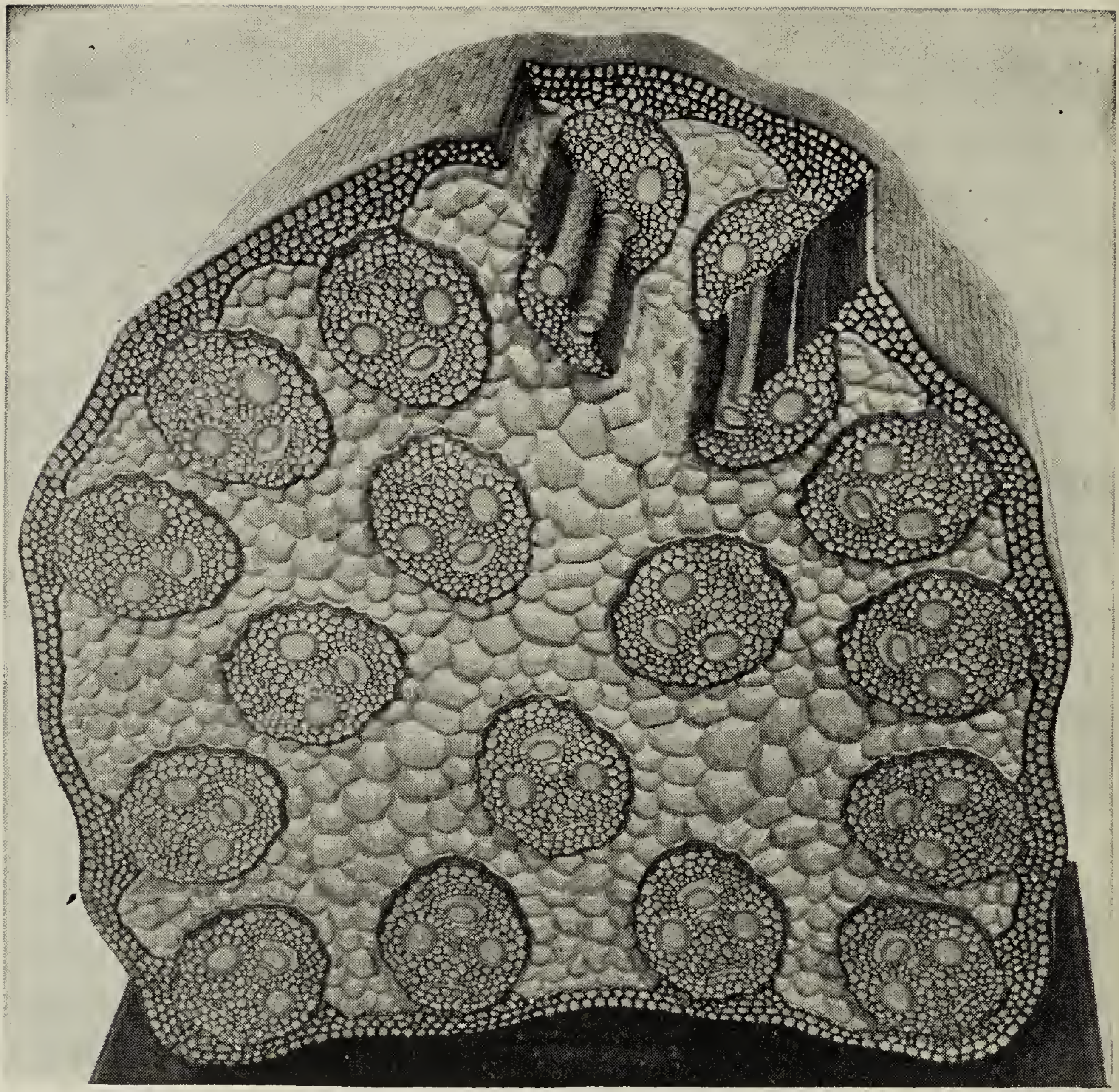

Fig. 27 Model of crosssection of a corn stem. (*Jewell Model Co.*)

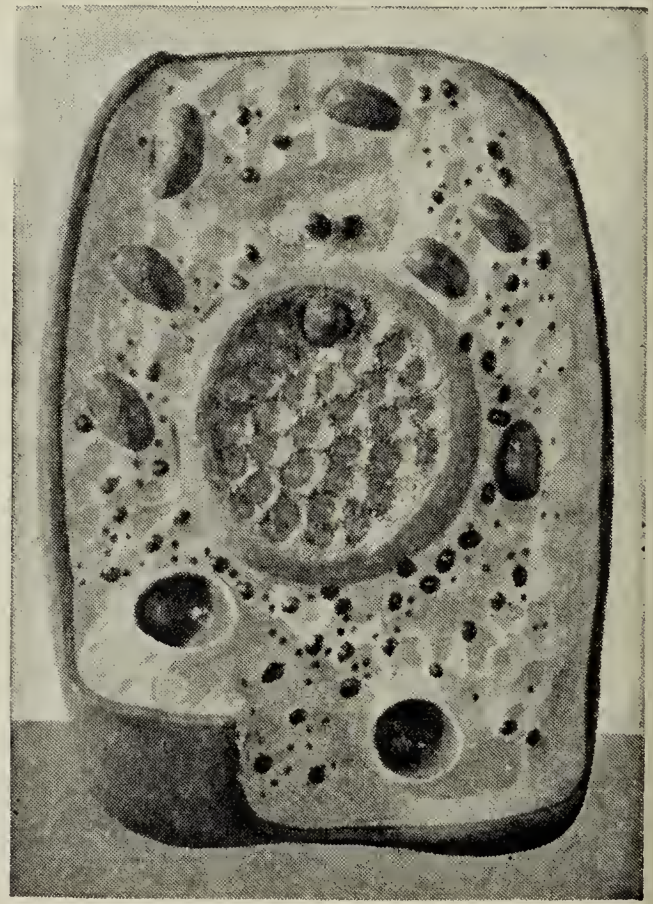

Fig. 28 Model of a cell. (*General Biological Supply House, Inc.*)

collected for the school museum: butterflies, moths, other adult insects, frogs, toads, snakes, turtles, salamanders; birds' nests, cocoons, larvae of insects, leaves, stems, fruits, roots, grasses, flowers, bark, tubers, bulbs, corms, mushrooms, lichens, and seeds.

Other sources of museum materials are as follows:

(1) *Public museums.* Science teachers should investigate nearby museums to determine whether any exhibits of specimens may be borrowed, rented, bought, or obtained for permanent use free of charge. Exhibits of raw materials such as latex, flax, wool, silk, cotton, and food stuffs may be obtained at a low cost from the Commercial Museum, Philadelphia.

(2) *Homes.* Teachers should encourage pupils to bring things from home which will serve to illustrate lessons. Household utensils, gadgets of various kinds, pictorial materials, books, etc., useful for a museum may be obtained in this way.

(3) *Local stores and industries.* Excellent museum materials may sometimes be obtained free from local stores and local industries or purchased at a low cost from stores such as five-and-ten-cent stores.

(4) *Butcher shops and slaughter houses.* These are good places for biology teachers to find anatomical specimens.

(5) *Scientific supply houses.* The following companies specialize in supplying objects, specimens, and models to schools. Science teachers should write to these firms for free catalogues.

Biological Supply Co., 1176 Mt. Hope Ave., Rochester, N. Y.
Cambridge Botanical Supply Co., Waverly, Mass.
Carolina Biological Supply Co., Elon College, N. C.
Central Scientific Co., 460 E. Ohio St., Chicago; 220 E. 42nd St., New York; 1121 S. Hill St., Los Angeles, Calif.; 79 Amherst St., Boston, Mass.
Chicago Apparatus Co., 1735 N. Ashland Ave., Chicago.
Clay-Adams Co., 25 East 26th St., New York (Models and charts).
Denoyer-Geppert Co., 5235 Ravenswood Ave., Chicago (Models and charts).
Empire Laboratory Supply Co., 559 West 132nd St., New York.
Fischer Scientific Co., 711 Forbes St., Pittsburg, Pa.
General Biological Supply House, 761–763 East 69th Place, Chicago.
Heil Corp., 210 S. Fourth St., St. Louis, Mo.
Kny-Scheerer Corp., 51–52 Twenty First St., New York.
Marine Biological Laboratory, Woods Hole, Mass.
Michigan Biological Supply House, 206 S. First St., Ann Arbor, Mich.
New York Biological Supply Co., 34 Union Square, New York.
A. J. Nystrom and Co., 3333 Elston Ave., Chicago (Charts).
Scientific Supplies Co., 123 Jackson Ave., Seattle, Wash.
Southern Biological Supply Co., 517 Decatur, New Orleans, La.

South-Western Biological Supply Corp., Dallas, Texas.
Standard Scientific Supply Corp., 12 W. 25th St., New York.
University Apparatus Co., 2229 McGee Ave., Berkeley, Calif.
Wards Natural Science Establishment, 302 N. Goodman, Rochester, N. Y.
W. M. Welch Scientific Co., 1515 Sedgwick St., Chicago.
Western Laboratories, 826 Q. St., Lincoln, Neb.

(6) *Corporations.* Many corporations, as a part of their publicity and advertising campaigns, have prepared exhibits which are useful in teaching science. Some of these exhibits may be obtained free of charge, whereas for others a small charge is made.

Suggestions and Helps for Collecting, Preserving, and Mounting Specimens

Animal life. The collecting of specimens can be made an integral part of field trips. Although the observation of living plants and animals in their natural environment is the main objective of field trips, collecting interesting specimens and bringing them back to the laboratory adds zest and interest to the work. The specimens, after they have been observed and studied by the pupils, should be preserved and made a part of an ever-growing biology museum. Table 3 gives directions for killing and preserving the commonly used laboratory animals.

The formulas for the special preserving solutions are as follows: Bouin's fluid: saturated picric acid solution, 75 cc.; formalin, 20 cc.; glacial acetic acid, 5 cc.

Carl's solution: 95 per cent alcohol, 170 cc.; formalin, 60 cc.; glacial acetic, 20 cc.; water, 280 cc. Do not add the acetic acid until just before using the solution.

Corrosive sublimate; concentrated solution. Do not mix in metal containers or stir with metal instruments, because they decompose the solution. Animals killed by corrosive sublimate should be washed carefully before being placed in alcohol.

Tellyesnicky's fluid: potassium bichromate, 3 gm.; glacial acetic acid, 5 cc.; distilled water, 100 cc.

The care of amoeba cultures in the laboratory. Protozoans of many kinds may be found in the stagnant water of ponds and ditches. Amoebae will nearly always be found on the undersides of lily leaves. Live cultures of amoebae may also be purchased from biological supply houses.

Amoebae are difficult to raise. The following points for maintaining amoeba cultures are recommended by the General Biological Supply House in *Turtox Service Leaflet No. 4:*

(1) Amoebae should be kept in shallow cultures. Water should never be more than one inch deep in the finger bowl.
(2) When the level of the water falls below this depth it is necessary to add water in very small quantities. Not more than a small pipette (medicine dropper) of pure distilled water should be added at daily intervals.
(3) Amoeba cultures should have a very small amount of food material present. Too much food material results in a too rapid increase of infusoria, which will crowd out the amoebae. A few ciliates, however, are not detrimental.
(4) If no wheat or hay is present in the culture when it is transferred to the finger bowl, add two pieces of boiled timothy hay stems, each one inch long, or if no timothy is available, three grains of boiled wheat.
(5) By placing the finger bowl on the stage of a binocular microscope, the relative number of amoebae present in the culture can be determined easily. Observe it from time to time; if the infusoria become too abundant it is probable that too much food is being used.
(6) If the amoebae become abundant the culture may be divided. To reculture proceed as follows:

Stir the culture well and pour into another clean finger bowl; then pour half of the water back into the old finger bowl. To each culture add two pieces of boiled timothy hay stem, one inch long, and cover cultures with glass plates. Every other day add a small pipette of pure distilled water to the culture. In this way bring the water level up to a depth of one inch. Check the progress of the culture by viewing it occasionally through the binocular microscope. These cultures should continue to flourish for a long time. After several weeks they may be recultured by following the same procedure.

Feeding aquarium and terrarium animals. To be successful in keeping live animals in the laboratory requires patience and care. The busy teacher should allow the more interested members of her class to take over the responsibility of caring for the animals kept in the classroom or laboratory. Before this is done, however, the teacher should be certain that the pupils know the life habits (especially the feeding habits) of the animals assigned to their care.

Animals kept in captivity frequently must be trained to eat. Much time and patience is sometimes required at first to get the animals to take their food. Cold-blooded animals (fish, frogs, toads, salamanders, reptiles, etc.) can go without food for long periods of time without harm. There is always more danger of overfeeding than underfeeding. The following suggestions[1] pertain to the food problems of common laboratory animals.

Snails. Snails relish fresh lettuce leaves and thrive on them. They also eat the algae in the aquarium tank (thus helping to keep the glass sides clear), aquatic plants, small pieces of meat, and powdered cuttle-fish bone. The last named is beneficial, as it develops their shells. In general, snails are scavengers, and if there are only a moderate number in a good-sized balanced aquarium, they will thrive without any special food or attention.

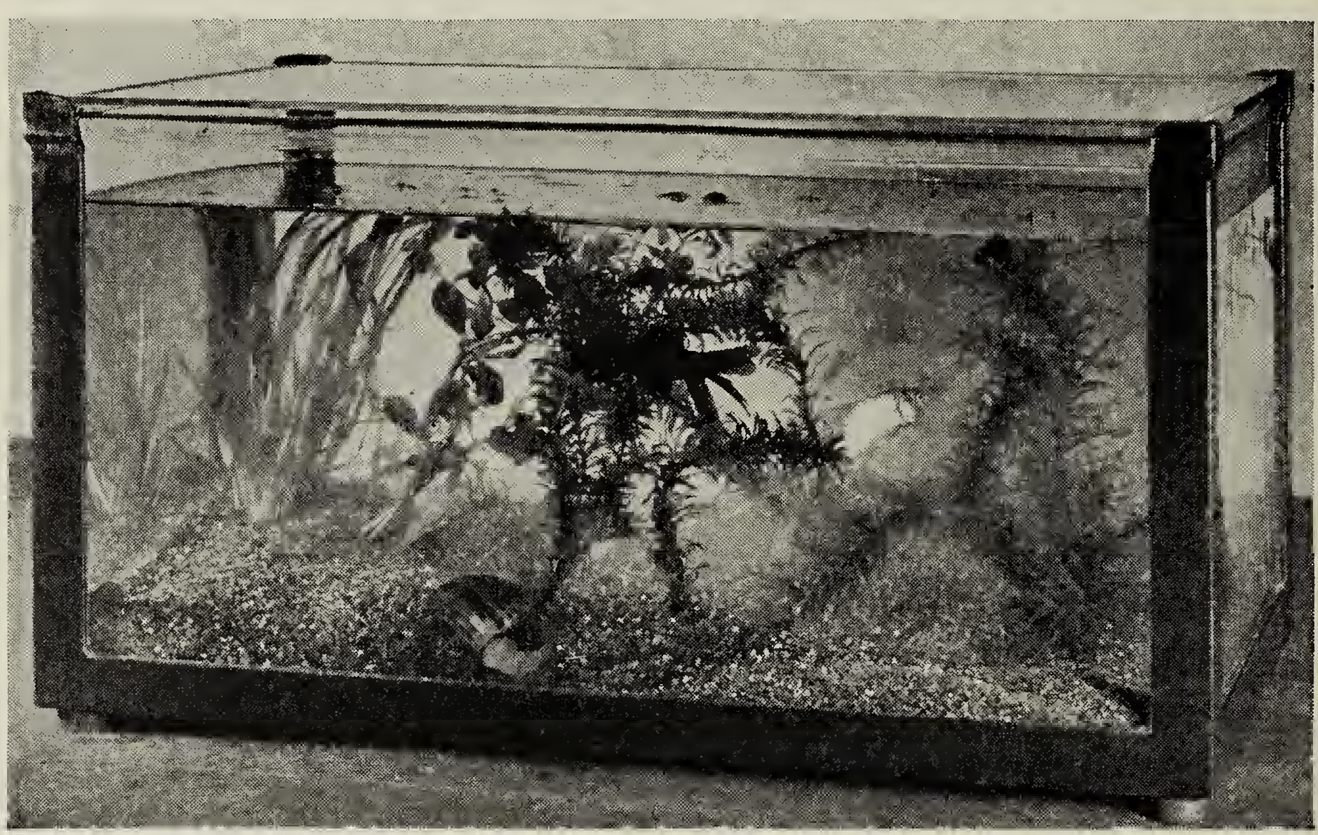

Fig. 29 A balanced aquarium. (*Central Scientific Co.*)

Snails found lying on the bottom of the tank with open operculum are dead and should be removed.

Fish. Fish demand a variety of foods, and the person who supplies them with a varied diet is sure to have the best results. Mix the diet with dried and live foods. If fish food is fed during the first part of the week, such living food as enchytrae, daphnia, or chopped mealworms should be used during the latter part of the week. Fish may be fed shredded beef, chopped oysters or clams, earthworms, mosquito larvae, canned lobster or shrimp, cereals, mealworms, daphnia and other small crustaceans, yolks of hard-boiled eggs, and boiled or baked white potatoes. Live foods may always be had, for it is possible to rear mealworms, enchytrae, and daphnia in the laboratory, and earthworms can easily be kept on hand for use during the winter months.

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[1] From *Turtox Service Leaflet No. 23,* General Biological Supply House.

Fish should be fed only every other day, or less often if the temperature is low. Overfeeding always causes more deaths than underfeeding.

Sickness among fish is common and is usually due to overcrowding, overfeeding, or the introduction of other sick fish to the tank. When a fish begins to act queerly, if white patches appear on its body, or if its tail and fins begin to fray, it should immediately be removed from the tank, as most fish diseases are contagious. Salt baths in either table salt or epsom salts are good and may be given healthy fish monthly to insure permanent health. Prepare salt baths as follows:

¾ teaspoonful table salt
¼ teaspoonful epsom salts
1 gallon water

Fish may be left in this bath twenty-four hours without harm. For a half-hour treatment, use the same proportions, only use a tablespoon for measuring. New fish should be subjected to the salt bath treatment before being placed in an established aquarium, in order to guard against the introduction of disease.

Salamanders. The most common vivarium salamander is the red-spotted newt. It will live in a balanced aquarium or in a semi-aquatic terrarium, although over long periods it probably thrives best in the latter.

Newts may be fed living fruit flies, enchytrae, very small earthworms, pieces of mealworms, shredded beef, scrambled eggs, fresh liver, and the like. In an outdoor tank or pond they will consume great quantities of mosquito larvae. If only one or two newts are to be cared for, they may be fed individually with pieces of food held with a pair of long forceps. However, if there are many, they should be fed living food or else transferred to a special dish for feeding so that the aquarium will not be fouled by an excess of food.

TABLE 3

THE COLLECTION AND PRESERVATION OF SOME OF THE COMMONLY USED LABORATORY ANIMALS*

Animals	Where Found	Special Collecting Tools	How to Kill	Fixative	Preservative
Fresh-water sponges	Midsummer in fresh water attached to branches and submerged wood.	Flat-bladed knife or scalpel.	70% alcohol changed when it becomes discolored.	70% alcohol.	70% alcohol.
Hydra	Lagoons, ponds, rivers, lakes attached to vegetation, stones, fallen leaves.	Flat-bladed knife or scalpel and pipette.	Hot Bouin's flooded over specimens from base to peristome.	Bouin's.	70% alcohol.
Fresh-water Planaria	Fresh spring-fed streams, lakes, rivers.	Fresh beef or liver placed in water where Planaria are found.	Extend on glass plate and submerge in hot Gilson's or corrosive sublimate.	Gilson's or corrosive sublimate.	Formalin or alcohol.
Tapeworms	Intestines of dogs, cats, rabbits, or sheep.	Scalpel and forceps.	Extend on blotting paper saturated with fixative.	Bouin's or formalin.	Alcohol or formalin.
Ascaris	Intestines of pigs, horses, cats, or dogs.	Scalpel and forceps.	Water heated to 98° C. Worms dipped momentarily.	5% formalin or saturated corrosive sublimate solution.	5% formalin or alcohol.

Rotifers	Plant material taken from ponds or lagoons and placed in jar.	Pipette.	Anesthetize with solution of cocain hydrochlorate 1 gram—alcohol 12 cc., water 50 cc. Dilute to 3 × volume.	When cilia cease to move, add few drops osmic acid.	Wash in H_2O and store in 10% formalin.
Pectinatella and plumatella	Attached to stems, rocks, leaves in streams, especially in late fall.	Scalpel.	When fully expanded, flood with boiling Bouin's.	Bouin's.	70% alcohol.
Earthworms	In spring on rainy nights on golf courses or blue grass lawns.	Flashlight and suitable clothing.	Anesthetize by slowly adding alcohol to water in which worms are placed. Lay out in pans and cover with formalin.	5% formalin.	5% formalin.
Leeches	Hand pick from hosts or with dip net among weeds in ponds and streams.	Dip net.	Anesthetize in warm chloretone or magnesium sulphate or asphyxiate in closed jar.	Inject with 10% formalin and submerge in same in extended position.	8% formalin.
Crayfish	Streams, ponds, lagoons in water or burrowed in mud.	Dip net, seine, or spade.	Drop alive into alcohol or 8% formalin.	70% alcohol or 8% formalin.	70% alcohol or 8% formalin.

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* The General Biological Supply House, Chicago, Ill.

TABLE 3—*Continued*

THE COLLECTION AND PRESERVATION OF SOME OF THE COMMONLY USED LABORATORY ANIMALS—*Continued*

ANIMALS	WHERE FOUND	SPECIAL COLLECTING TOOLS	HOW TO KILL	FIXATIVE	PRESERVATIVE
Ticks and mites	Cattle, dogs, horses, old cheese, decaying organic matter.	White paper and brush for taking specimens from parasitized animals.	Drop directly into 70% alcohol.	70% alcohol.	70% alcohol.
Centipedes and millipedes	Under logs or stones.	Forceps.	Carl's solution.	Carl's solution injected into body cavity	Carl's solution.
Insects	Woods, fields, water, air—everywhere.	Nets, forceps, and other equipment depending on kind collected.	For drying, in killing jar. For liquid preservation, in alcohol.	Alcohol, Carl's solution, chloral hydrate, and special solutions.	Alcohol, Carl's solution, or drying.
Slugs	In damp places under leaves, logs, stones, etc.		Anesthetize in boiled water (cooled) and immerse in formalin or alcohol.	Alcohol or formalin.	70% alcohol or 8% formalin.
Aquatic snails	Streams, ponds, lagoons, lakes. Most abundant among vegetation.	Dip net, scraper net.	Anesthetize in warm water by adding magnesium sulphate, causing them to ex-	10% formalin.	8% formalin.

			pand, then drop into 10% formalin.		
Clams	Streams, lakes, partly buried in the bottom.	For large numbers a dredge or crowfoot hooks are used.	Place wooden pegs between the two halves of shell and drop into 10% formalin.	10% formalin.	8% formalin.
Lampreys	Occasionally may be taken from fish, but for large numbers must be taken in breeding season in streams.	Seine.	Remove from water for few minutes and inject 10% formalin in body cavity.	10% formalin.	8% formalin.
Fishes	Streams, lakes.	Nets, seines, or hook and line depending on kind.	Drop into full strength formalin.	10% formalin.	8% formalin.
Grassfrogs	In meadows or borders of marshy lakes.	Net.	Inject ether into body cavity or drop into 80% alcohol.	Inject 5% formalin into body cavity and place in 5% formalin.	5% formalin.

TABLE 3—*Continued*

THE COLLECTION AND PRESERVATION OF SOME OF THE COMMONLY USED LABORATORY ANIMALS

Animals	Where Found	Special Collecting Tools	How to Kill	Fixative	Preservative
Grassfrog eggs	Shallow water of ponds in early spring when singing is started.		Place in fixative.	8% formalin or Tellyesnicky's.	8% formalin.
Salamanders	Damp places in woods, ponds, rivers, streams, sloughs.	Hook and line or nets depending on kind.	Inject ether into body cavity and drop into 8% alcohol.	5% formalin.	5% formalin injected into body cavity.
Reptiles	Woods, fields, dunes, depending on kind.	Snares for handling poisonous forms. Nets for capturing turtles and aquatic forms.	Inject ether into body cavity.	10% formalin.	8% formalin injected into body cavity.
Birds and small mammals	Most of world.	For taxidermy purposes a 12 gauge shotgun and shot shells with fine shot. (No. 8 or No. 12.)	Bird skins are generally used for study or reference purposes. Body is removed and skin dusted with arsenic powder. Skin is then stuffed with cotton, and dried.		

Larger salamanders, such as Ambystoma, Triturus torosus, Phethodon, and Eurycea, live best in a semi-aquatic tank. Their food, however, is the same as that described above for the red-spotted newt.

Grassfrogs. The grassfrog or leopard frog must always be kept in a semi-aquatic condition so that he may take to or leave the water at will. If the frogs are kept cool this will slow down the metabolic processes and lessen the need for food. In nature, the frogs range in the grasses near the water and eat insects. In the laboratory this is hard to duplicate, but they will eat flies and other small insects dropped to them and, occasionally, they will eat small earthworms.

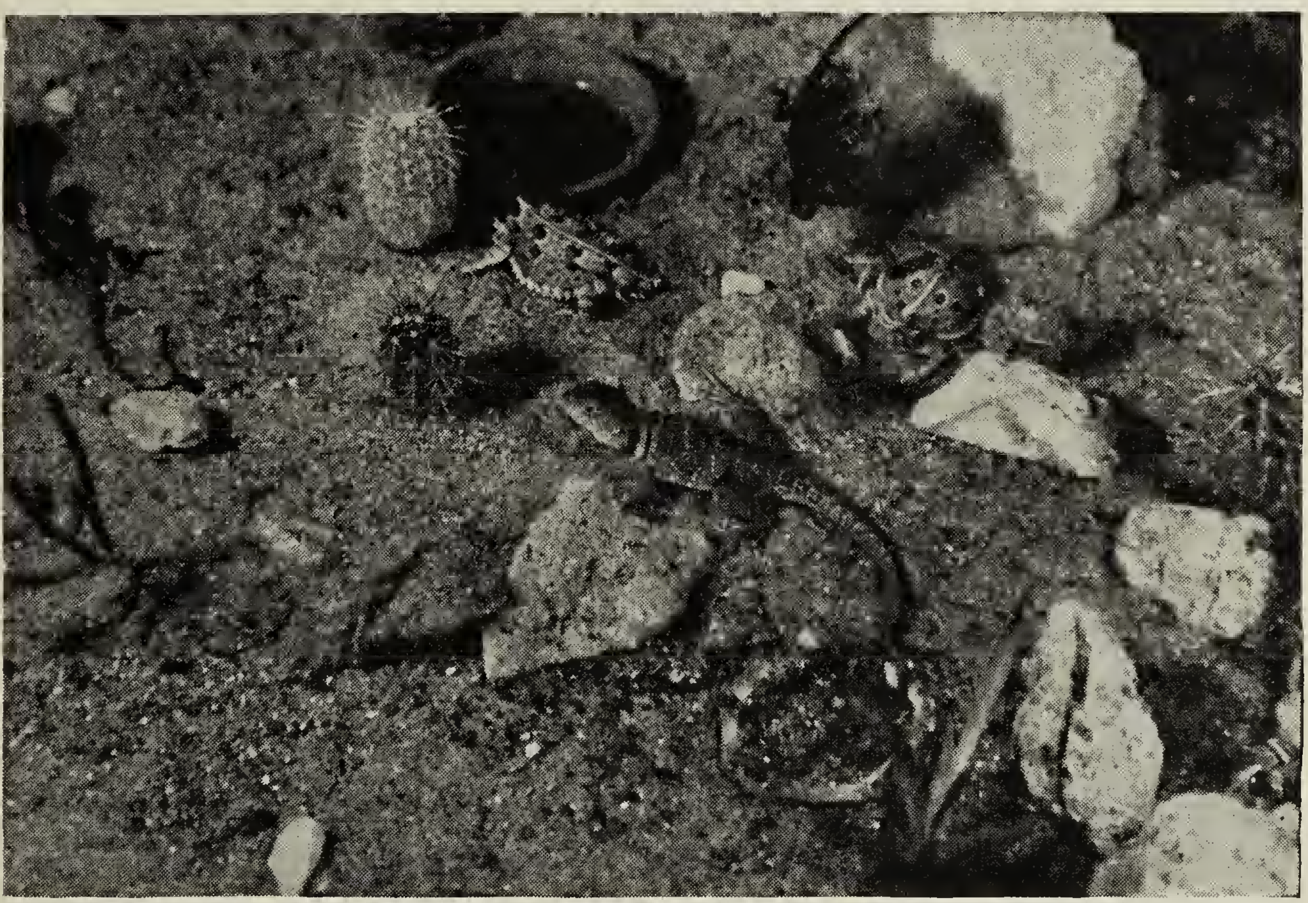

Fig. 30 A desert habitat. (*General Biological Supply House, Inc.*)

Tree frogs. Tree frogs should be kept in a semi-aquatic terrarium or in a woodland terrarium where there is plenty of moisture. They must have hiding places, such as clusters of ferns, mosses, small flowering plants, etc., where they can avoid the sun. In the average terrarium tree frogs will usually remain hidden during the day, coming out at night to feed. If food is provided during the day, however, they will soon learn to accept it.

Tree frogs live largely on insects and will take living Drosophila (fruit flies), mealworms, and roaches, all of which can be reared in the laboratory. Just release the living insects in the terrarium, and the frogs will soon find them.

Land turtles. Land turtles require warmth and sunshine, as well as some moisture. They drink much water and will become sick if they do not get enough. Their favorite foods are snails, slugs, maggots, over-ripe fruit (especially bananas), lettuce, carrots, and clover. They are not heavy eaters and often fast for long periods. Land turtles usually hibernate. If kept in a warm place in the autumn they will refuse food and water and eventually die unless they are given a cool place in which to sleep for several months.

Their commonest illness is eye trouble, in which the eyelids become fastened down and covered with scales. The remedy is to bathe the eyes in a 3% boracic or salicylic acid solution several times a day. These animals also catch cold if left in a draft or if they live in too damp a place. This causes heavy breathing and loss of appetite, and in extreme cases brings on death.

Aquatic turtles. Aquatic turtles find their food in swampy and moist places and then drag it into the water to eat. Therefore, it is wrong to try to feed aquatic turtles on land, as they need water to wash their food down. Semi-aquatic conditions are needed for water turtles, as they do at times go up on land. Sand in one end is best, as this gives them a chance to bury themselves and avoid strong sunlight. They relish ground meats, fresh fish, tadpoles, mealworms, aquatic insects, and scrambled eggs, and at times some aquatic turtles will eat vegetative foods. Aquatic, as well as terrestrial turtles, go on long hunger strikes and refuse to eat. Force feeding is useless and usually does more harm than good. If mold appears on the shell, apply the same salt baths as given to fishes.

Lizards. Many lizards have cannibalistic tendencies. Therefore, it is not advisable to place too many species together.

They also have a strong fighting tendency and will do much jumping, hissing, and running when they are about to be caught. Anolis (chameleons) require much sunlight and heat, live in branches, and should be watered daily. The best way is to sprinkle the water on the branches and let them drink or lap it up as they would dew. Feed them roaches, flies, crickets, mealworms, and other living insects.

Horned "toads," which are lizards and not toads, require a high temperature (80–90° F.) if they are to eat. In winter place them near a radiator for several hours before attempting to feed them. They require a terrarium with several inches of dry sand on the bottom, as on cold days and nights they like to bury themselves in the sand. Feed them mealworms, ants, cockroaches, and other living insects.

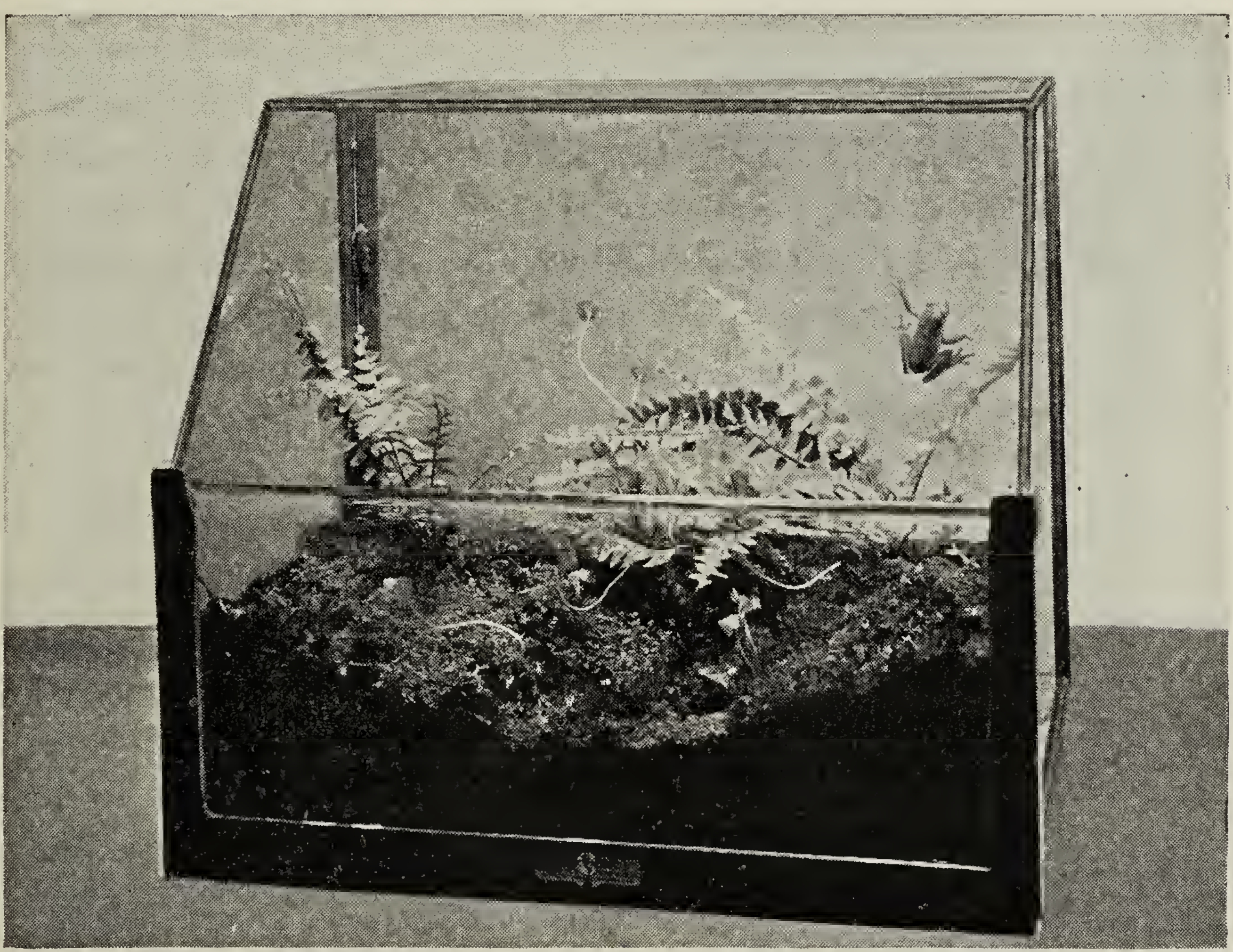

Fig. 31 A terrarium of woodland plants. (*Courtesy of General Biological Supply House, Inc., Chicago, Ill.*)

Alligators. Alligators require a semi-aquatic vivarium so that they may swim or sun themselves. They must have warmth (75–85° F.). They catch food in the sides of their mouths and drag it under water to swallow. Feed by dangling food to one side of their nose and they will soon snatch it and swim away with it. They eat fresh beef, liver, scrambled eggs, mealworms, tadpoles, cockroaches, and fish.

Snakes. The terrarium for snakes should have a sand bottom and should also contain branches that may assist the snake in shedding its skin. Snakes desire warmth and concealment. The food for snakes must be alive and will have to move before they will attack it. Small frogs, tadpoles, rats, mice, lizards, and mealworms are the best foods for snakes. At times, however, snakes will eat fresh beef if it is moved about before them either on a string or held by forceps. Do not keep small snakes with large ones or you will soon have only large ones.

Preserving plant specimens. Plants are, for the most part, easier to preserve than animals. Plant specimens which are not to be used for microscopic work may be readily preserved in a four per cent solution of formaldehyde. Very large, fleshy forms may require about a six per cent solution.

While a solution of formaldehyde is widely used to preserve plants, it has two disadvantages: a disagreeable odor and its ability to bleach the plants. The following formula is recommended because it will not destroy the green color of plants:

50% alcohol	90 cc.
40% formalin	5 cc.
Glycerine	2.5 cc.
Glacial acetic acid	2.5 cc.
Copper chloride	10 gm.
Uranium nitrate	1.5 gm.

The specimens are left in this solution until needed. About ten days are required for complete preservation. If the odor of formaldehyde is too offensive, the specimens should be thoroughly washed in water and kept in a weak solution of ammonia, at least a day, before they are to be studied in the laboratory.

Fruits such as apples may be preserved by use of the following formula:

Distilled water	4000 cc.
Zinc chloride	200 gm.
Formalin (40%)	100 cc.
Glycerine	100 cc.

Mushrooms may be preserved in their natural color in the following solution:

40% formalin	6 cc.
50% alcohol	100 cc.

Lichens do not require a preserving solution. Dry them, and soak them a few hours in water before they are needed for study.

Home-Made Models and Dioramas

Teachers of science have been discovering that keener interest and better understanding may result when pupils make or help in making models. The following techniques have been used by Mr. Fletcher J. Proctor, a teacher of biology. Mr. Proctor says, "The method used, by our pupils, in making models of a corn seed is as follows. First make a plaster of Paris block 6 in. by 11 in. by 1 in. by mixing the plaster and pouring it into a cake tin or, even better, a pyrex cake dish for the latter gives the finished block a nice gloss. A pyrex dish also gives the worker a chance to make sure that no air bubbles form on the under side of the block for that will be the working surface. Before starting, the dish should be coated thinly with lard, Spry, or olive oil. If the finished product is to be mounted as a plaque with wooden background a means of attachment must be provided before the plaster sets hard. Ordinary paper clips that have been straightened out can be partially imbedded in the plaster while it is still pliable. After this has been done, allow it to set for a day or two and the block will leave the dish easily when the latter is inverted. The next step is to make an enlarged cross sectional sketch of a corn seed. This should be made from an actual

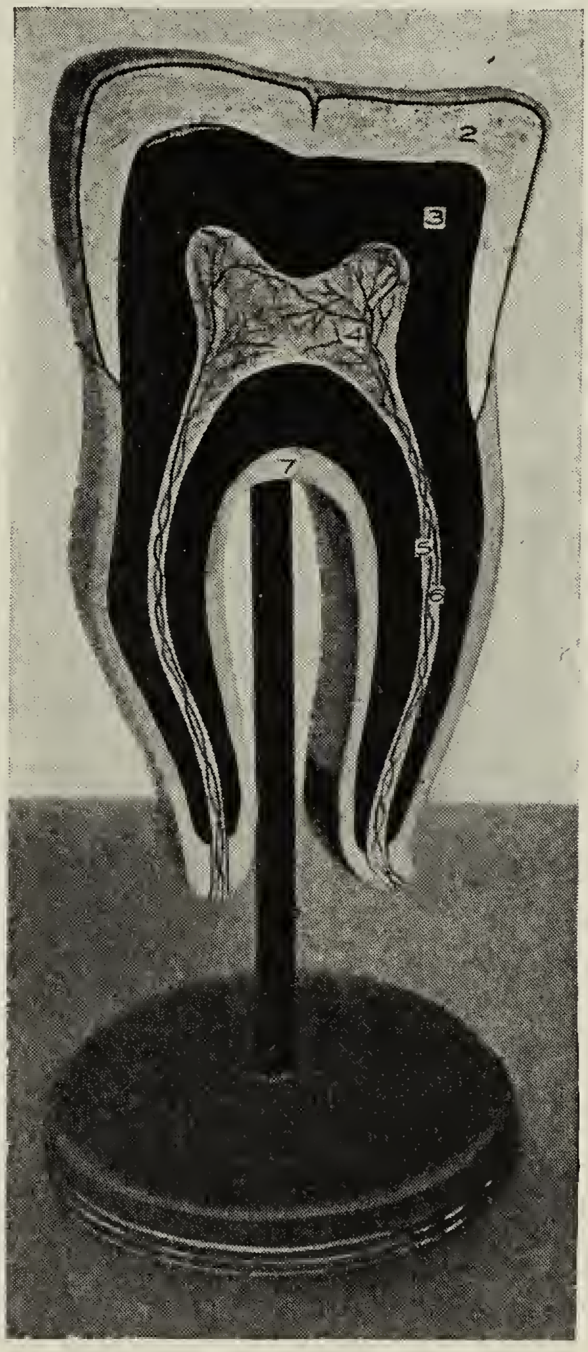

Fig. 32 A student made model of a tooth. *(Courtesy of Fletcher J. Proctor.)*

dissection observed under a dissecting microscope to insure accuracy. After an accurate drawing has been made, place a piece of carbon paper under it and trace the drawing on to the working surface of the plaster block. If done carefully the tracing will serve as an easy guide for the carving operation which can be completed with an old scalpel and a sharp implement such as a geometry compass. Use the latter to trace trenches where outlines are desired and ink them in with Higgins red or black ink. Trenches keep the ink from spreading. If colors are needed to make certain areas stand out ordinary water colors will do very well if water is used sparingly. Numbers for identification of parts can be made on the typewriter, cut out, and pasted on as desired. Any scratches or rough edges that remain after the carving is finished can be smoothed out with a small strip of fine sandpaper. Colorless fingernail polish will give the finished plaque a protective coating and leave a nice gloss on the finished product. Plaques and models have been made by the above method at costs as low as fifty cents each. Bases for the latter are easily made of wood. The important thing to remember in work of this type is that pupils must do it all or the real educational values of such projects are lost.

"Plaster of Paris leaf prints are also wonderful aids in a study of compound and simple leaves, veining and leaf margins, especially at times of the year when live material is not available or is difficult to obtain. Grease the pyrex dish used above and arrange a leaf on the bottom. Mix a fine batten of plaster and pour over the leaf, being careful that none gets under the edges and that it does not move. Put the dish away for a few days until the plaster has dried out and then remove the cast as described previously. Leaves usually adhere to the plaster but are easily stripped off, leaving an excellent print which will show all the required parts. To finish the plaque paint the print with colors to match the actual specimen, using a fine brush. A good leaf-green paint can be obtained at any five-and-ten-cent store. Work of this nature is instructive and interesting, and through it we are able to stimulate some of the otherwise hard-to-reach pupils."

Many things are studied in science which cannot be brought into the classroom; for example, dinosaurs, an oil well, or a coal mine.

In such cases the studying is generally done with pictures and charts. Museums have been performing a valuable service to science education by reproducing nearly exact images of things and processes in their natural settings. This type of model is called a *diorama.* It is one of the best visual aids yet devised because it enables pupils to visualize objects in their natural environment.

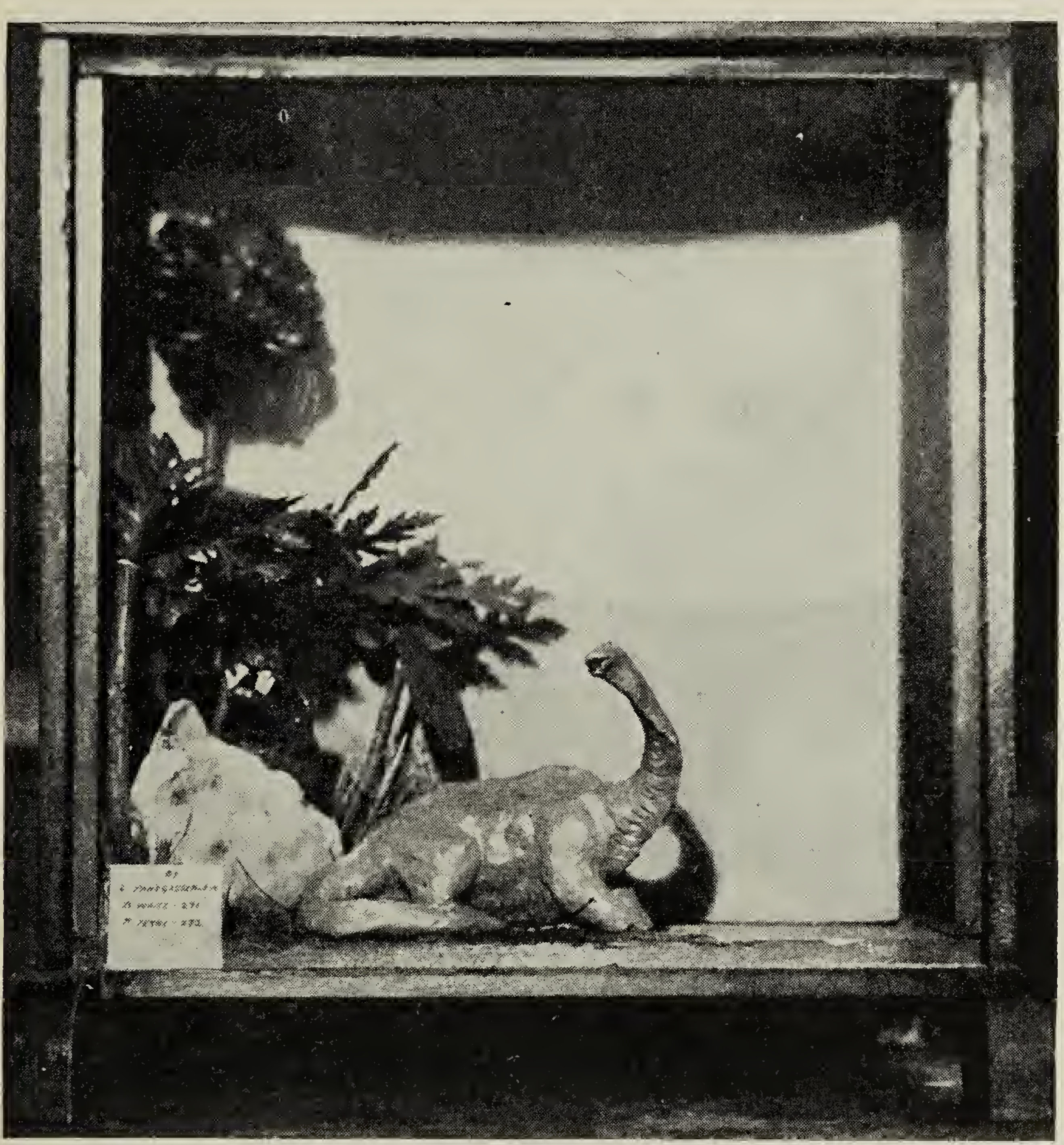

Fig. 33 A diorama. A student project in biology. (*Courtesy of Charles W. Gouget.*)

Mr. Charles W. Gouget[2] of Austin High School, Chicago, who has been experimenting with this kind of visual aid says, "A model or a diorama becomes still more instructive, and more objective and understandable, if it has been made by the student himself. Such a task requires careful observation of details to be able to complete it according to any pre-conceived ideas. It involves, also, the exercise of a certain amount of judgment, together with artistic and mechanical skills to turn out a worth-while product. The lasting results of learning acquired in this manner, and the training afforded by the work involved cannot be overestimated.

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[2] Gouget, C. W., "An Objective Approach to Biology," *The American Biology Teacher,* I:81–83, 1939.

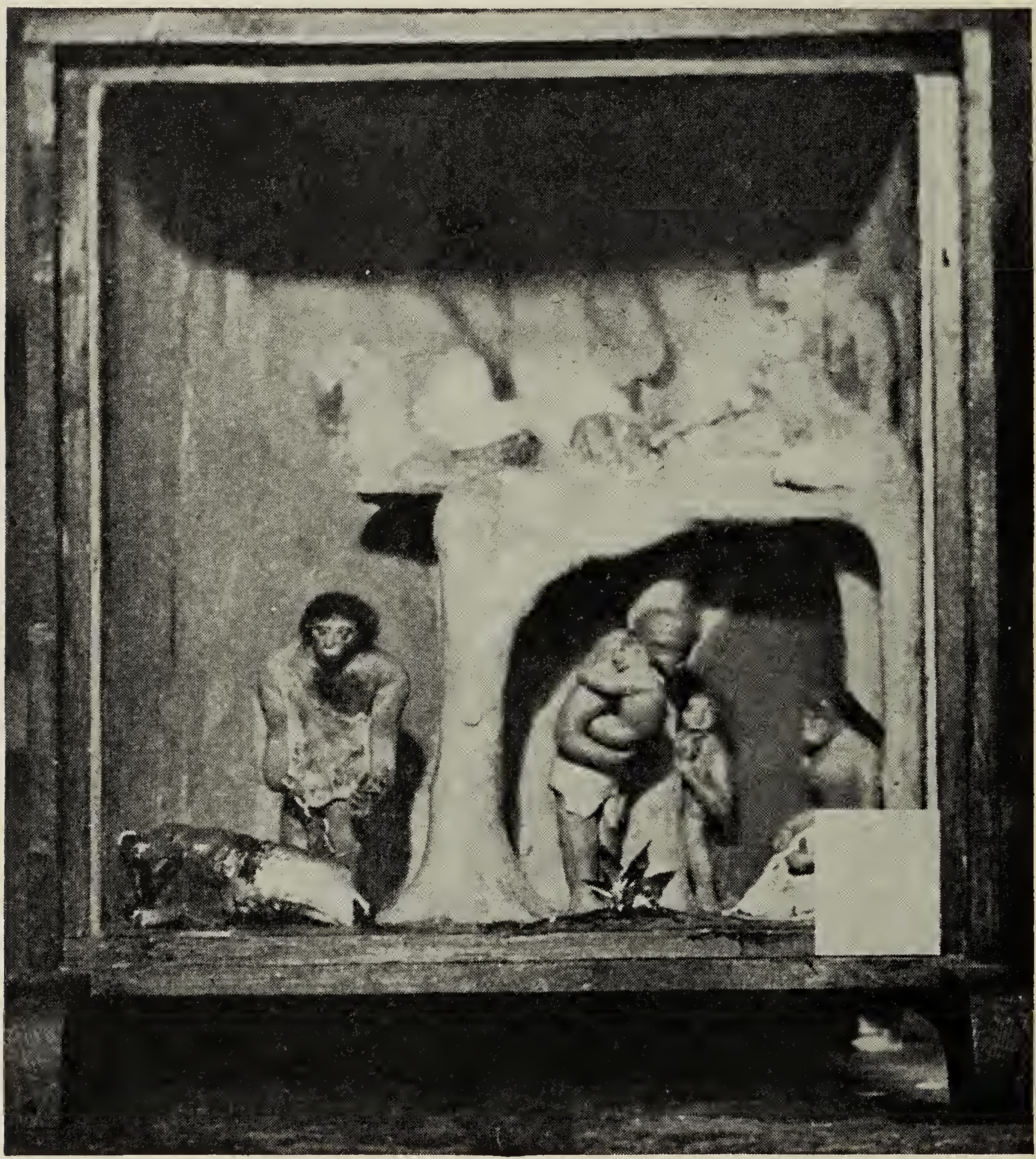

Fig. 34 A diorama. A student project in biology. (*Courtesy of Charles W. Gouget.*)

"The tremendous possibilities of plastic clay in producing permanent, miniature dioramas for the classroom have scarcely been touched. A few of these possibilities are shown in the illustrations. Plastic clay will not deteriorate with age, nor melt in warm weather. It can readily be torn down and built over, a fact which is most important in producing good work among high-school students. In addition it can be painted with oil paints or poster colors to which no water has been added. When the figures are properly supported, and protected by glass in a diorama case, the exhibit becomes a permanent addition to the classroom. Each new addition creates new interest and spurs group activity towards the completion of a museum as the ultimate goal in the Biology Classroom.

"It is not hard to 'sell' a subject to a student on an activity basis, if interesting objective results of previous activities can be exhibited by the teacher."

QUESTIONS AND EXERCISES

1. Define the terms object, specimen and model.
2. Why are objects ideal visual aids?
3. Why are specimens not quite as valuable as objects in teaching science?
4. Suppose you were a biology teacher and you used a model of a paramecium to teach about this one-celled animal. What incorrect concepts may be formed in the pupils' minds?
5. If you were planning to organize a science museum in your school, where would you look for museum materials?
6. Suppose you planned to keep the following live animals in the classroom: snails, fish, salamanders, frogs, snakes, alligators. What kind of habitat would you provide them? What would you feed these animals?
7. What is a diorama? How can miniature dioramas be made for use in the science classroom?

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Chapter 18

DESIGNED MATERIALS

This field of visual aids offers a wide variety of materials to science teachers. Designed materials, when properly employed, tend to promote a keener interest in science and a better understanding of scientific concepts by the pupils.

Certain qualities are desirable in designed materials. First, there is the quality of *simplicity*. The human mind tends to react slowly. One stimulus of intense strength is of more value than several of weaker strength. In general, one idea clearly expressed in a chart or graph gives the best results.

Second, there is a quality of *attractiveness*. Each visual aid should possess appeal. Through the proper use of colors, design, and neatness of arrangement, all designed materials may be made attractive to pupils.

Third, the proper arrangement of these visual aids enhances their value as teaching aids. A classroom in which the visual aids are poorly arranged detracts from their value. Designed materials for a particular science unit should be exhibited only during the time when study of the unit is in progress. They are not meant to be used as classroom decorations, and should be made large enough to insure perfect visibility through the entire classroom.

Equipment needed. In order to carry out a program of designed materials the following equipment is recommended:

(1) Wrapping paper for rough or temporary use.
(2) Bristol board, 22 in. by 26 in., in all colors.
(3) Muslin or sign-painters cloth.
(4) Ball-pointed or spoon-bill pens.
(5) Paint brushes #5, 7, and 11, for all colors.
(6) Rubber stamps (1 inch) for letters or figures.
(7) Drawing instruments (small size).

(8) Show-card paints, crayons, and chalk of all colors.
(9) Stencils for frequently reproduced items.
(10) Costumes made by the clothing department.
(11) Stage scenery and equipment made by the manual training department.
(12) Lighting and projection equipment.

Kinds of Designed Materials

Home-made and commercial charts. The purpose of any chart is to give a clearer meaning to the idea which it represents. Usually a chart is a flat surface upon which images have been drawn. Charts are generally accompanied by an explanation or so-called "legend." Color may or may not be used, but the proper use of colors often increases the value of the chart.

In science classes, a common chart is that known as the "Geologic Time Chart." This is shown in Figure 35. The purpose here is to aid in the study of the development of animal life through the various geological eras. It may be drawn on the blackboard or in a notebook.

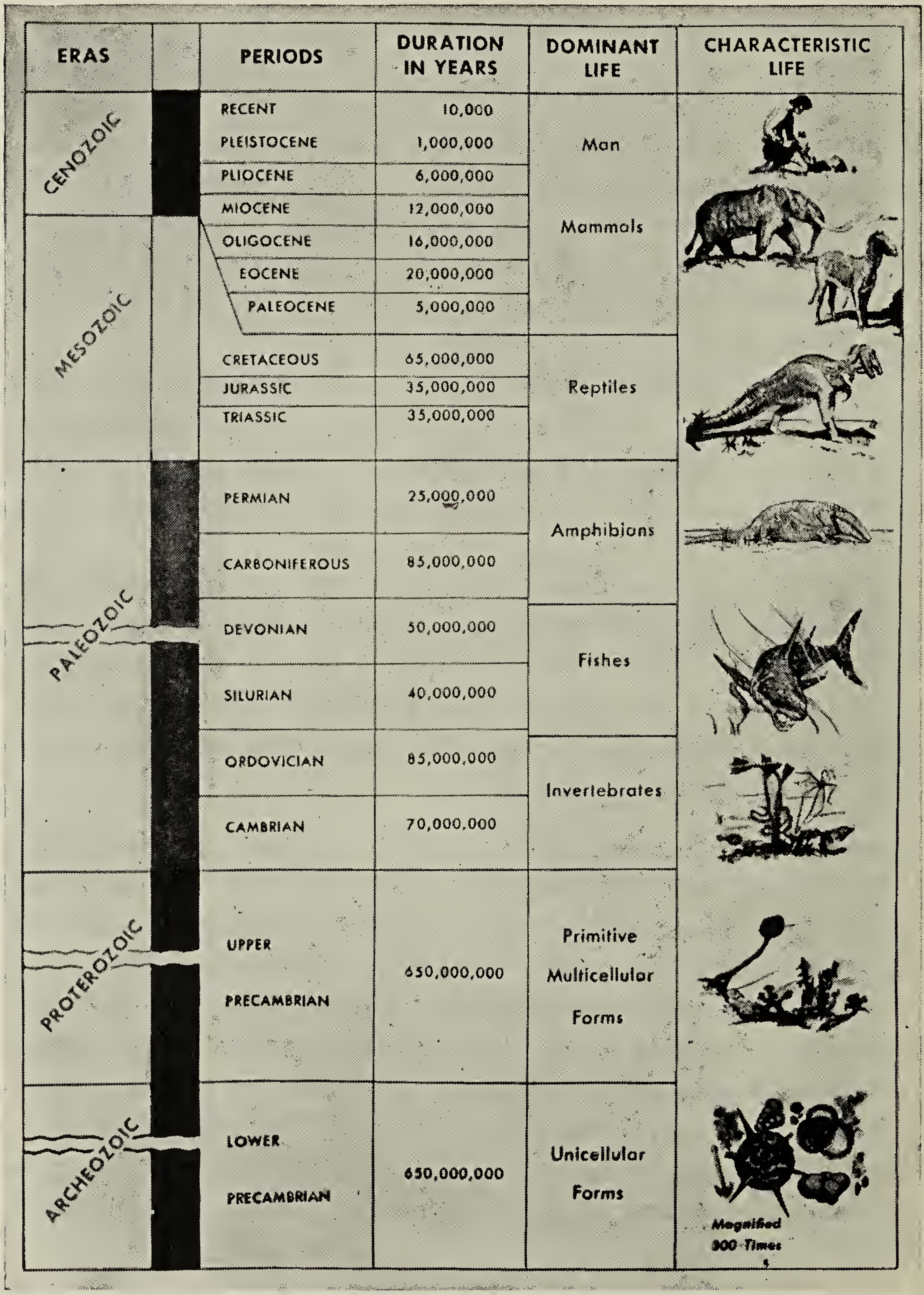
In elementary or secondary science student-made charts are helpful. They help to fasten an idea or subject firmly in the mind of the child. They need not be too technical but can be composed of a collection of pictures or drawings of objects seen on the school journey or in the classroom. The child should label each drawing or object on the composite chart.

Home-made and commercial posters. The poster, as a visual aid, is widely used and is very effective. Like the chart, the poster expresses the main thought or idea. Here too, the use of color and designs helps to build up the appeal.

Students should be encouraged to make posters. The fields for the subject are many. Some of these are: astronomy, agriculture, animals, biology, clothing, chemistry, communication, diets, foods, health, industrial processes, radio, and safety. The poster is of value where the project method of teaching is used. The poster also provides an endless source of interest for those pupils with ability and interest in drawing.

It is generally desirable for the teacher to give some instruction to the pupils in cutting out pictures, drawing lines, and using color to advantage. No particular training is needed in art or design.

Even the blackboard may become a poster, as it usually does during Christmas festivities at school. At this time the blackboards



ERAS	PERIODS	DURATION IN YEARS	DOMINANT LIFE	CHARACTERISTIC LIFE
CENOZOIC	RECENT	10,000	Man	
	PLEISTOCENE	1,000,000		
	PLIOCENE	6,000,000		
	MIOCENE	12,000,000	Mammals	
MESOZOIC	OLIGOCENE	16,000,000		
	EOCENE	20,000,000		
	PALEOCENE	5,000,000		
	CRETACEOUS	65,000,000	Reptiles	
	JURASSIC	35,000,000		
	TRIASSIC	35,000,000		
PALEOZOIC	PERMIAN	25,000,000	Amphibians	
	CARBONIFEROUS	85,000,000		
	DEVONIAN	50,000,000	Fishes	
	SILURIAN	40,000,000		
	ORDOVICIAN	85,000,000	Invertebrates	
	CAMBRIAN	70,000,000		
PROTEROZOIC	UPPER PRECAMBRIAN	650,000,000	Primitive Multicellular Forms	
ARCHEOZOIC	LOWER PRECAMBRIAN	650,000,000	Unicellular Forms	Magnified 300 Times

Fig. 35 A geologic time chart. (*Sinclair Refining Co.*)

are usually resplendent with various drawings of Saint Nicholas and his reindeer. Red and green colors are used for effectiveness.

Lately the poster has been employed as a subtle means of spreading propaganda. Commercial companies use this type of visual aid by having advertisements on billboards, car cards, newspapers, wrapping paper, and magazines.

Graphs. A graph is a drawing which represents a fact or a group of facts or an idea. A graph is a chart form of presenting statistics.

Graphs are useful to the teacher in several ways.

(1) They help the teacher in focusing the attention of the pupil in the direction desired.
(2) They make it easier for the pupils to grasp the meaning of statistical data.
(3) They help to clarify thinking with reference to facts.
(4) The help to arouse interest in statistical data.

If graphic materials are integrated with other visual aids they will increase the effectiveness of the science unit.

The blackboard and the bulletin board may be used as media for the display of graphic materials. The following suggestions are offered as a means of making the blackboard a more efficient device for the visualization of scientific data and concepts:

(1) Graphs, whether made by teachers or pupils, should be an expression of their best efforts.
(2) Too many graphs or charts on the blackboard at one time may divide attention. It is recommended that only one or several be exposed to the students' attention at one time.
(3) Graphs should be definitely related to the topic under study or discussion.
(4) Drawings on the blackboard should be clearly visible to all the students in the room.

When constructing a graph the student should work from left to right on the material used. A "legend" or "explanation" should accompany the graph and be plainly legible. Whenever possible the writing of this explanation and also the labeling of the graph should be written horizontally. It is best to outline the graph in pencil first and then carefully use ink. Care is required here, as careless inking of a graph may destroy it scientific accuracy.

KINDS OF GRAPHS

Bar graph. These graphs have either a line of varying width or bar to indicate the facts. A row of bars or series of columns may represent a series of closely connected facts.

Vertical bar graph. The vertical bar graph is constructed with the bars placed on the horizontal or base line. The value of each bar is determined from a vertical scale.

Horizontal bar graph. In a horizontal bar graph the bars are placed on a vertical or base line. The value of the bars is determined from a horizontal scale. Horizontal bars are preferable to vertical bars. The eye can compare horizontal distances more easily than vertical distances.

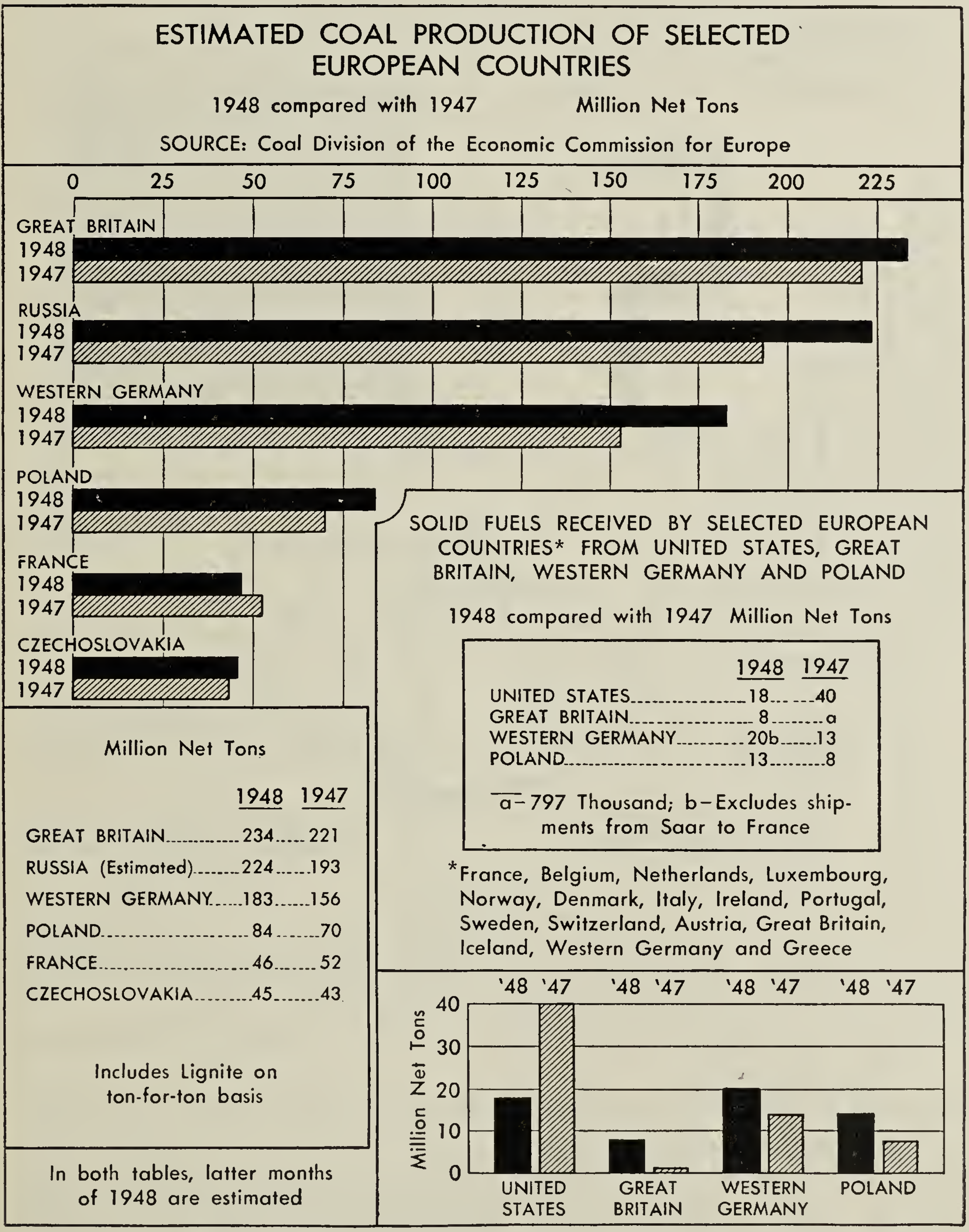
Component bar graphs. Sometimes in bar graphs the bars are divided into component parts to show related facts. Since the bar is the whole, it is divided into as many parts as desired, depending on how many components are to be represented. Each component is represented differently from the other by various devices such as shading, cross-hatching, filling-in with colors, or heavy outlining.

Component bar graphs may be made to scale or not to scale. If they are not made to scale, the values are usually marked on the bars. With a scale, this marking is not necessary. Examples of some bar graphs are shown in Figure 36.

Circle representations. Circle graphs are used to show percentage or fractional values of a whole. To make circle graphs accurately requires the use of a compass and a protractor for measuring degrees and laying off angles. The following general rules in teaching pupils how to make circle graphs will be helpful:

(1) Make sectored circle graphs in preference to concentric circles. Concentric circles are difficult to compare.
(2) Print all titles neatly at the top of the graph.
(3) Whenever possible print labels within the circle in a horizontal line.

Sectored-circle graph. In making a sectored-circle graph the percentage values are reduced to degrees, and the space measured with the aid of a protractor. One per cent of value is represented by an arc of 3.6 degrees. Twenty-five per cent of value is measured by an arc of 90 degrees. Since the eye cannot estimate accurately the percentage value or fraction of the whole for each sector, it is advisable to label each sector with its percentage value. Shading or coloring the sectors, or the use of dots or cross-hatching, will aid in differentiating the sectors and making the graph more attractive. An example of a sectored-circle is given in Figure 37.



ESTIMATED COAL PRODUCTION OF SELECTED EUROPEAN COUNTRIES

1948 compared with 1947 Million Net Tons

SOURCE: Coal Division of the Economic Commission for Europe

Million Net Tons

	1948	1947
GREAT BRITAIN	234	221
RUSSIA (Estimated)	224	193
WESTERN GERMANY	183	156
POLAND	84	70
FRANCE	46	52
CZECHOSLOVAKIA	45	43

Includes Lignite on ton-for-ton basis

In both tables, latter months of 1948 are estimated

SOLID FUELS RECEIVED BY SELECTED EUROPEAN COUNTRIES* FROM UNITED STATES, GREAT BRITAIN, WESTERN GERMANY AND POLAND

1948 compared with 1947 Million Net Tons

	1948	1947
UNITED STATES	18	40
GREAT BRITAIN	8	a
WESTERN GERMANY	20b	13
POLAND	13	8

a–797 Thousand; b–Excludes shipments from Saar to France

*France, Belgium, Netherlands, Luxembourg, Norway, Denmark, Italy, Ireland, Portugal, Sweden, Switzerland, Austria, Great Britain, Iceland, Western Germany and Greece

Fig. 36 Examples of bar graphs. (*Bituminous Coal Institute, Washington, D.C.*)

Curve graph. The curve graph is widely used in the scientific and industrial world to show trends of facts and variability. Every science teacher should understand how to plot curves and how to read them. The following general rules should prove helpful in constructing curve graphs:

(1) The zero line of the scale for a curve should be heavy and sharply distinguished from the other coördinate lines.
(2) It is advisable not to show any more coördinate lines than are necessary to guide the eye in reading the diagram.

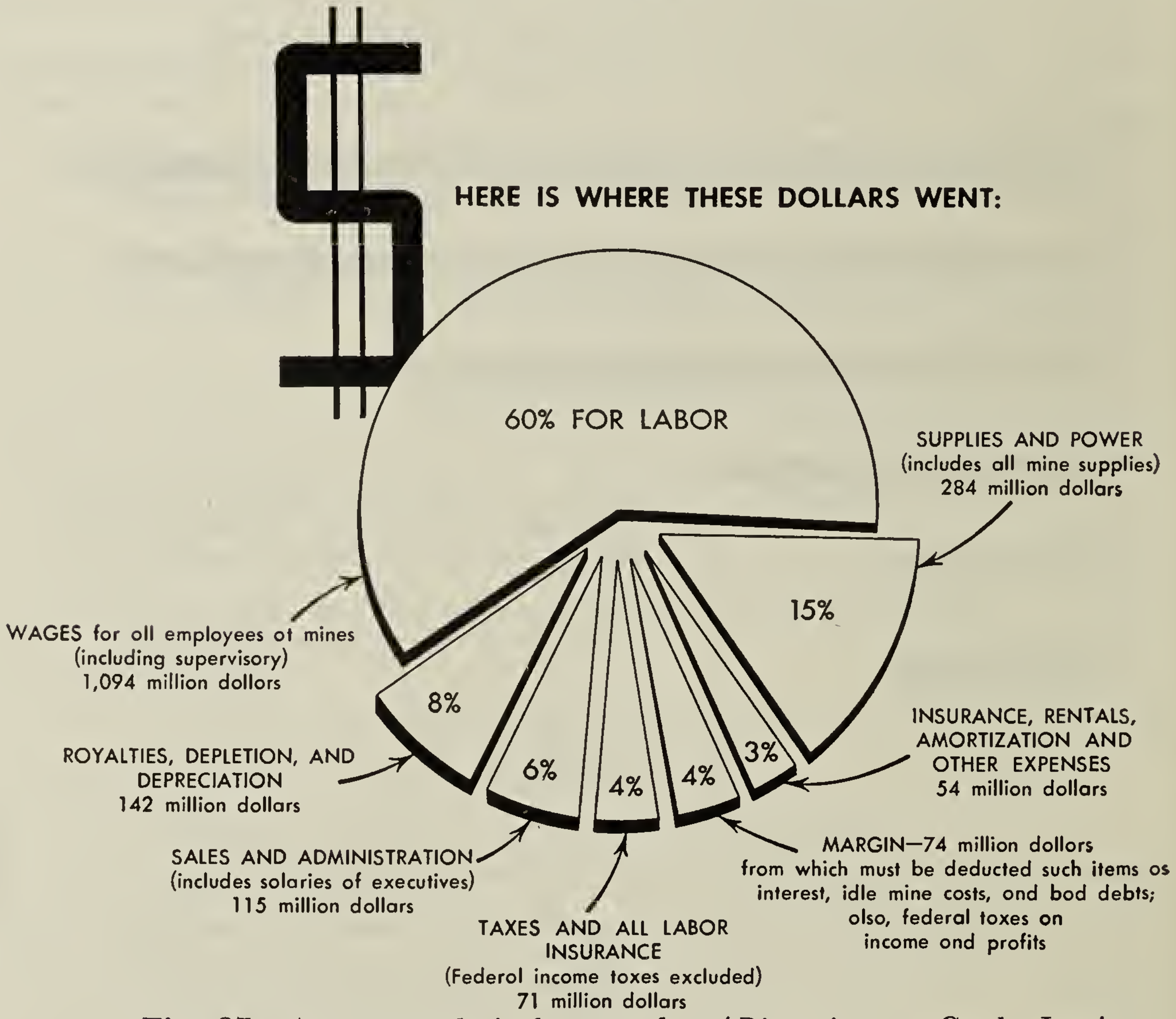
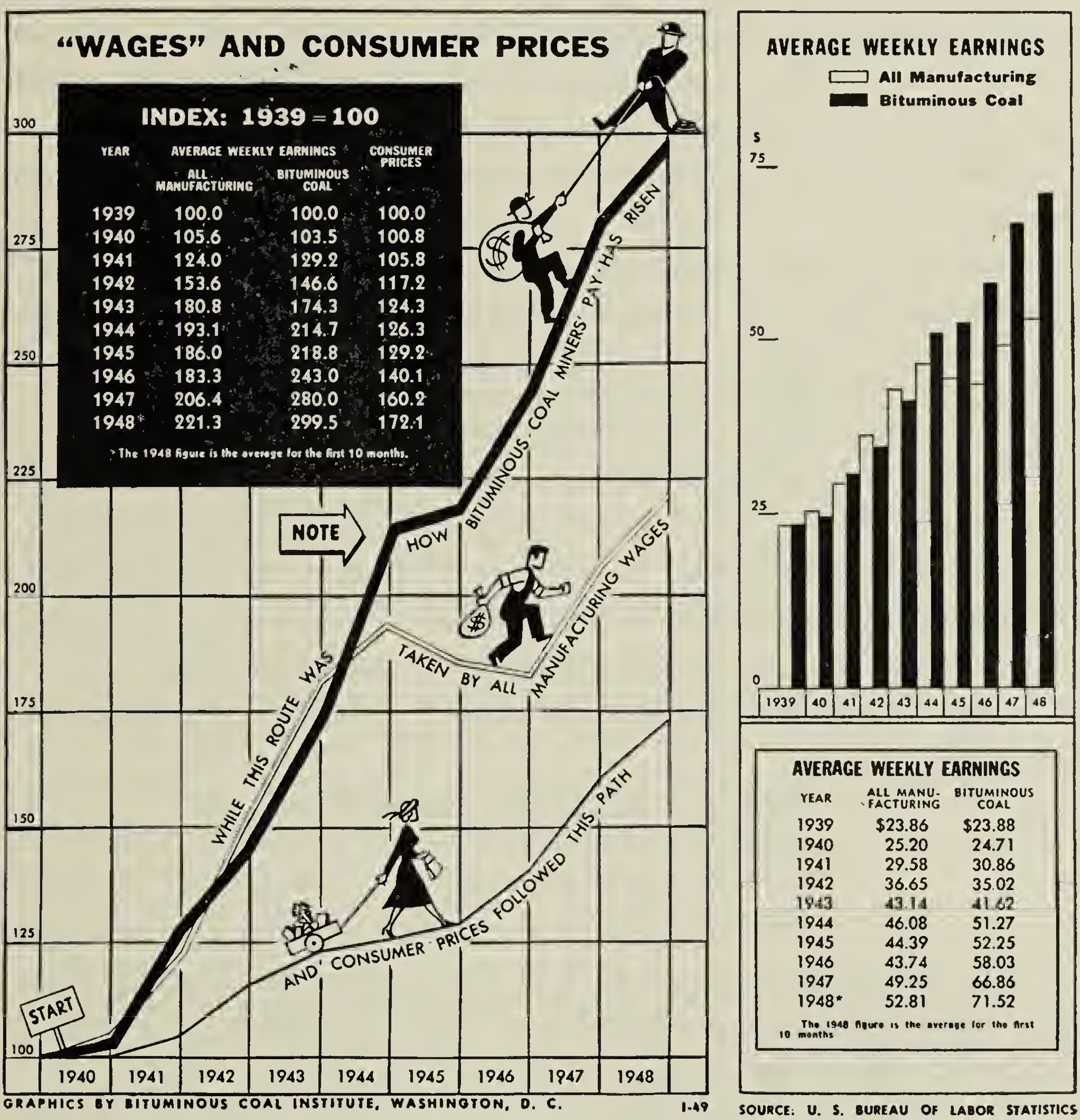


Fig. 37 A sectored-circle graph. (*Bituminous Coal Institute, Washington, D.C.*)

(3) The curve lines of a diagram should be sharply distinguished from the ruling.
(4) The horizontal scale should read from left to right and the vertical scale from bottom to top.
(5) Figures for the scale should be placed along the respective axes.
(6) The title of the diagram should be made clear and as complete as possible. Subtitles or descriptions should be added if necessary to insure clearness.

(7) In plotting curves, neatness and accuracy should always be striven for. A hard-edged ruler and a sharp pencil are necessary for accurate work.

The curve graph, when carefully made, is highly accurate. It is less attractive, however, than some other kinds of graphs. It is preferred by scientists, and statisticians whose reports are mainly for technical use and for whom attractiveness is of minor importance. An example of a curve is shown in Fig. 38.



INDEX: 1939 = 100

YEAR	AVERAGE WEEKLY EARNINGS ALL MANUFACTURING	AVERAGE WEEKLY EARNINGS BITUMINOUS COAL	CONSUMER PRICES
1939	100.0	100.0	100.0
1940	105.6	103.5	100.8
1941	124.0	129.2	105.8
1942	153.6	146.6	117.2
1943	180.8	174.3	124.3
1944	193.1	214.7	126.3
1945	186.0	218.8	129.2
1946	183.3	243.0	140.1
1947	206.4	280.0	160.2
1948*	221.3	299.5	172.1

* The 1948 figure is the average for the first 10 months.

AVERAGE WEEKLY EARNINGS

YEAR	ALL MANUFACTURING	BITUMINOUS COAL
1939	$23.86	$23.88
1940	25.20	24.71
1941	29.58	30.86
1942	36.65	35.02
1943	43.14	41.62
1944	46.08	51.27
1945	44.39	52.25
1946	43.74	58.03
1947	49.25	66.86
1948*	52.81	71.52

The 1948 figure is the average for the first 10 months

GRAPHICS BY BITUMINOUS COAL INSTITUTE, WASHINGTON, D. C. 1-49

SOURCE: U. S. BUREAU OF LABOR STATISTICS

Fig. 38 A curve graph. (*Bituminous Coal Institute, Washington, D.C.*)

Area graphs. Any geometrical figure which will show comparisons by size differences may be used to express simple areas. The most common figures for graphic representation of this kind are: squares, triangles, rectangles, and circles.

Picture graphs. Picture graphs are charts in which quantities are represented by means of pictorial symbols. The symbol used is always a likeness of the thing which it represents. Wherever data lend themselves to symbolic representation it is recommended that they be graphed in pictorial form. Picture graphs tend to animate statistics and make data concrete and interesting which would otherwise be dull and abstract.

The following rules should be considered before making picture graphs:

(1) Symbols should be self-explanatory.
(2) Larger values are shown by a larger quantity of symbols and not by larger symbols.
(3) Graphs compare approximate quantities—not minute details.
(4) Only comparisons should be graphed—not isolated statements.

The pictorial symbols used in picture graphs should be selected with special reference to the laws of association; data pertaining to war might be represented by guns or battleships or soldiers. Data pertaining to peace might be represented by the dove as a symbol. The student thus associates the symbol with a certain topic.

Color is also symbolic and associated with various objects. For example:

Red. . . . .fire, blood, war, Indians
Blue. . . . .sky, water
Brown. . .ground, wood
Black. . . .death, dejection

The ladder picture graph. This graph naturally suggests a rise to a higher plane, such as a rise in fame, education, or prices. A ladder is used as the symbol.

The thermometer picture graph. This form of graph is also suggestive of a rise in value or height. It may be used to represent temperature rise, water rise, etc.

THE DIAGRAM

The diagram is essentially a blue print of a process depicting some continuity, order, development, or procedure. In the diagram, facts or ideas are reduced to skeletal forms. No matter what is portrayed in the diagram, the basic interrelationship of facts is ever present. In this sense, the diagram is the most abstract of visual aids.

Certain factors may operate to make the diagram effective and meaningful. Previous discussion in the classroom will add interest. The school journey will supply some basis for detailed study. This may be such a topic as an industrial process or architectural planning of a house. Whenever the diagram is used it should be used as a follow-up technique.

The application of the diagram as a visual aid in science teaching is apparent. Certain scientific laws and concepts lend themselves easily to this method of illustration. The laws of falling bodies, the laws of motion, and the laws of heredity may all be illustrated by the diagram. Such concreteness of illustration as the step-by-step development in the diagram is an important advantage.

No special technique is needed in making a diagram. If the blackboard or notebook is used, the diagram can be outlined lightly at first, and then drawn in bold relief later. The pupil will often do this, particularly if developing the diagram step by step in class. Then too, colors may be added to suit the requirements and, if used, will aid in the effectiveness.

The effectiveness of the diagram will depend on its visibility. Unless the lettering, numerals, or other means of identification are plainly visible, they will be of little use. Elimination of nonessentials, prevention of crowding, and strong drawing will assist in the readability of the diagram.

THE CARTOON

The cartoon is an illustration dramatizing or emphasizing a fact (or facts) by means of satire, humor, fantasy, or incongruity. The cartoon is a very popular form of visual aid. When properly used, the cartoon is very effective in teaching certain phases of science.

The cartoon has universal appeal. Several ways of strengthening and increasing this appeal are as follows:

(1) Avoid technicalities by simplifying the facts or ideas of the cartoon. This will stimulate the imagination of the pupil and create additional interest.

(2) Associate the facts in the cartoon with experiences common to the pupil's daily life.

(3) Supply enough explanation or "dialogue," if necessary, to make the cartoon understandable.

(4) Make the drawing of the cartoon strong and bold for visual effectiveness. Weak lines in a drawing have little or no appeal.

(5) Select the proper symbols for the cartoon. The symbol chosen should be suggestive of the fact to be portrayed. For example: the dove portrays peace: the book portrays education or learning.

(6) Whenever possible, apply the proper use of colors to the cartoon. Even colors are symbolic. Use the complementary colors if contrast is desired; that is red and green, blue and yellow, black and white.

An example of a science cartoon is shown in Figure 39.

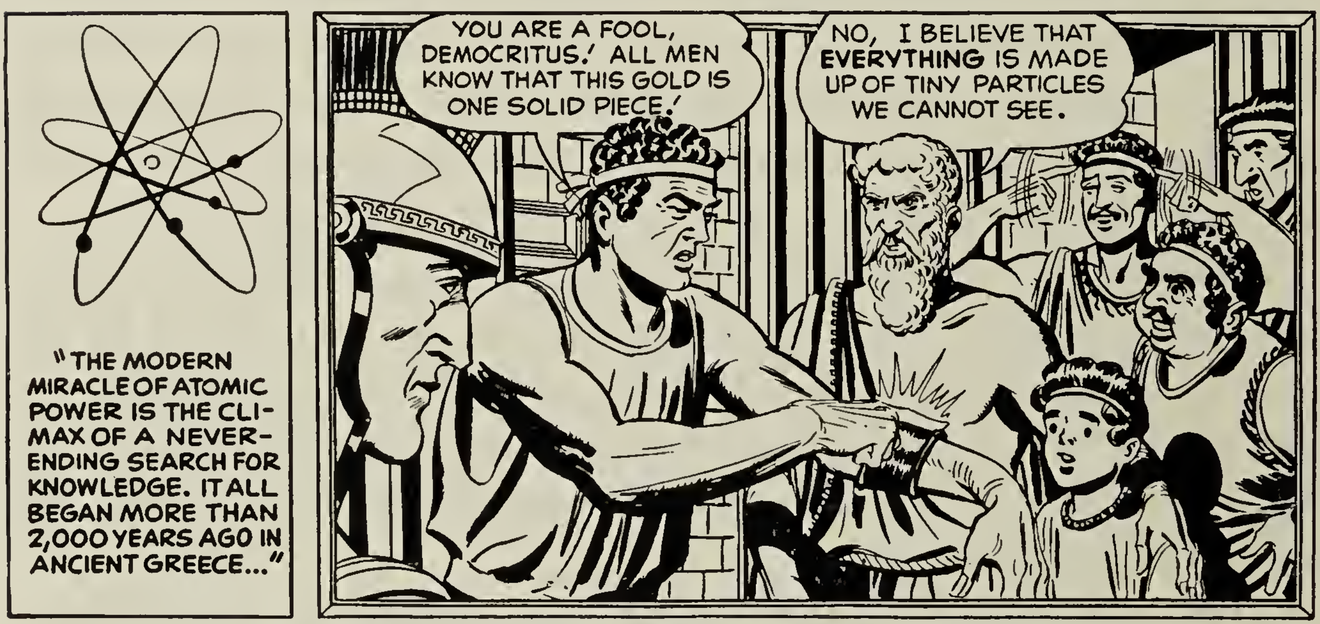

"THE MODERN MIRACLE OF ATOMIC POWER IS THE CLIMAX OF A NEVER-ENDING SEARCH FOR KNOWLEDGE. IT ALL BEGAN MORE THAN 2,000 YEARS AGO IN ANCIENT GREECE..."
YOU ARE A FOOL, DEMOCRITUS! ALL MEN KNOW THAT THIS GOLD IS ONE SOLID PIECE!
NO, I BELIEVE THAT EVERYTHING IS MADE UP OF TINY PARTICLES WE CANNOT SEE.

Fig. 39 A science cartoon. (*Courtesy General Electric Company, from "Adventures Inside the Atom," Copyright 1948, General Comics, Inc., New York.*)

The cartoon is not a blue print. Technicality of drawing is not the factor to be gained. The cartoon often has more effect if freehand drawing is used. Each pupil can then make and design the cartoon or cartoons, with the teacher as a guiding factor. The entertainment appeal will be much greater if students are allowed this freedom.

The cartoon is being applied daily to the sciences. The study of health is being fostered by countless advertisements in cartoon or comic strip form.

MAPS AND GLOBES

Maps and globes have long been associated with the teaching of history and geography, but a proper place should also be given them in the field of science. These visual aids are necessary for successful teaching of such special science fields as physiography, topography, meteorology, and geology.

The purpose of a map or a globe is to present concretely features of the earth, such as natural boundaries, topography, regions of water, ice, and land. The map or globe may present other conditions as follows:

(1) Climatic conditions—weather, arid and fertile areas, wind velocity, temperature.
(2) Time considerations—the Analemma, time dial, time belts. There are various kinds of maps and globes.

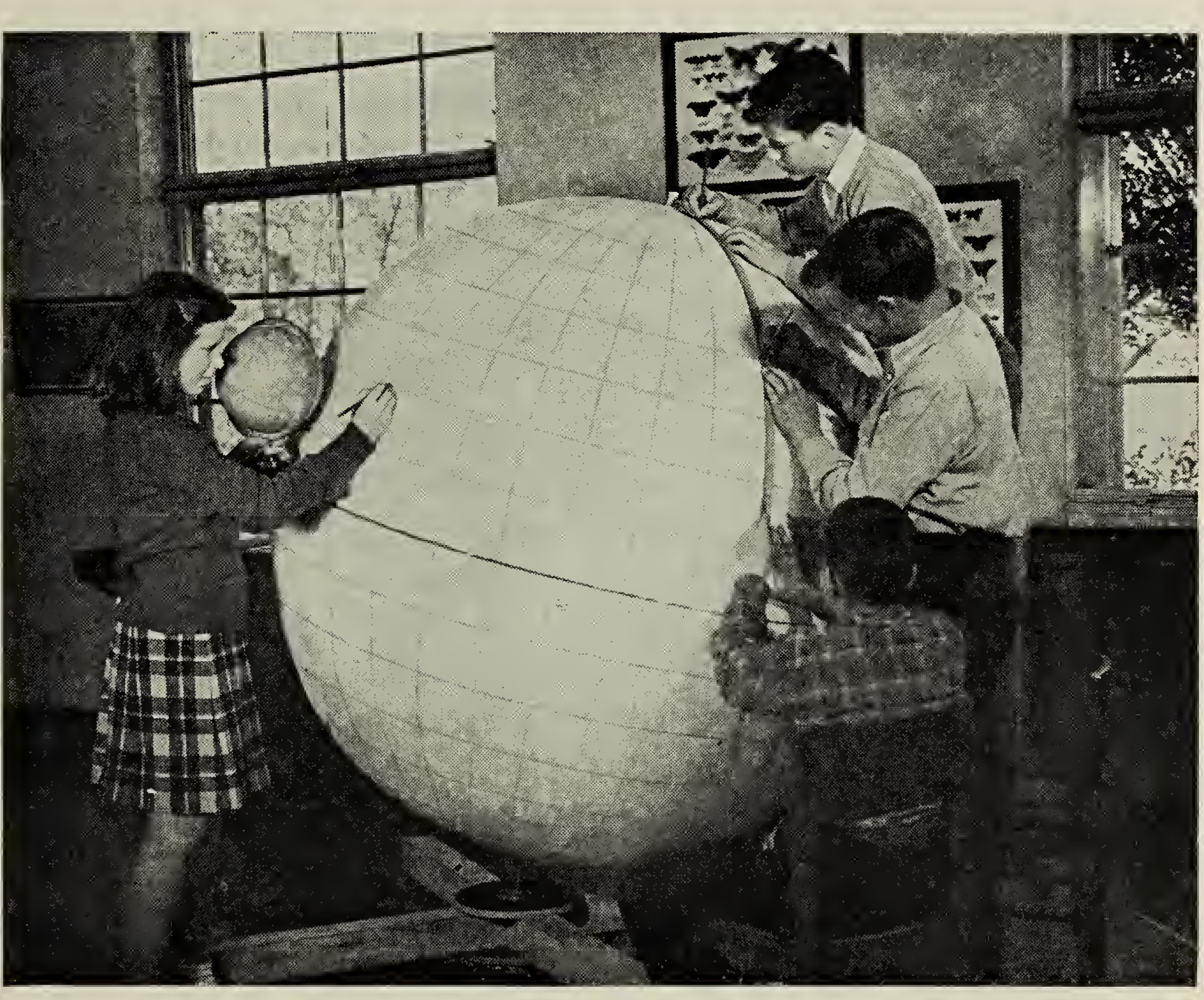


Fig. 40 Globe construction. (*Courtesy of John Sternig, Asst. Superintendent, Glencoe Public Schools, Glencoe, Ill.*)

Relief maps and globes. These visual aids give concrete impressions of surface conditions. They show elevations and depressions. Such a map or globe can be made by the student. Usually plastic material (paper, pulp, plaster, or soap) is spread on cardboard. Indentations are made in the soft material and then allowed to harden. Relief maps and globes are not highly accurate because of the tremendous size of the earth in comparison to the map or globe. Nevertheless pupils do gain a more nearly correct impression of surface conditions of the earth from these visual aids than is possible without them.

Physical maps and globes. These visual aids give information about the physical characteristics of geographical regions. They are of three types:

(1) *Graphic relief* indicates elevations of land above sea level by light and dark shades. Shows natural topography and roughness.

(2) *Contour layer* intervals between the contours are colored or shaded: generally blue for ocean, green for lowlands, and red and yellow for highlands.

(3) *Natural region* made to show natural regions. The regions follow the most important surface relief features of the earth. By means of a special color scheme these maps give a clear picture of the distribution of mountains, plateaus, plains, and uplands over geographic areas.

Weather maps. Weather maps show climatic and weather conditions of a region. Conditions of temperature, rainfall, wind velocity and air pressure are shown. The symbols which are used to represent the physical quantities are given on the map.

Economic maps. An economic map shows the products of a region.

Dramatization

In formulating plans for the use of a dramatic aid in science teaching the selection of a proper vehicle of dramatization is important. The following methods of dramatization may be considered.

The play. This is generally a stage performance where lines are spoken by the players during the act.

The teacher who depends entirely on the science dramas presented in the classroom or school auditorium, is overlooking two useful modern media, radio and television. The development of atomic energy, radar and other applications of science is producing increased numbers of science programs on the air that are educational and instructive. Some schools are now wired for sound so that radio programs can be "channeled" to classrooms. In other schools the teachers bring in small portable radios and tune in science programs for their classes. Since television is making vast inroads into school systems by providing science dramas through telecasting actual classrooms, quiz programs and on-the-spot events, this teaching medium cannot be overlooked.

The science teacher who wishes to become familar with other information concerning radio and television, should read Chapter 22, Sound Systems, or obtain more information from the references at the end of this chapter.

Radio dramas. One of the major networks, the Columbia Broadcasting System, has a science department of its own and is preparing science dramas with wide appeal. Other programs, such as KDKA's "School of the Air" or CBS's "American School of the Air" long maintained teaching projects. The American Chemical Society, for example is actively cooperating with various radio stations and presents "Headlines in Chemistry" over Station WNYC in New York. Other broadcasts devoted to science and having very important science implications are "Science in the News," "Frontiers of Democracy," "Americans at Work," "The World Is Yours."

The basis of a science drama on the air is in the preparation and delivery of the script. Such scripts, to be effective, must be dramatic, well-paced and have abundant human appeal. The teacher who presents these dramas to classes by radio or takes part in their preparation and actual delivery over the air can judge the program or script on some of the following items:

(1) The subject to be dramatised should be one which is interesting and important to everyday life.
(2) The approach is best if non-technical and based on human experiences.
(3) The scientific material in the program should bear directly on the subject and fit naturally into it.
(4) The script or program should be well-paced to provide human interest, such as sharing or merging of viewpoints if opinions are given.
(5) The "flashback" technique, if present, should be clear-cut and skillfully handled to prevent misconceptions or confusions to the listener.
(6) Conversational parts of the program or script, particularly science interviews, should not be lengthy, or too formalised. Many such conversations are even better if "somewhat ad libbed," with a layman present.

(7) Science news, especially that resulting from research, should emphasize its social and political implications.

Some radio stations furnish scripts to the teachers using their programs. Program directors generally assist the teacher in the preparation of their own scripts. In any event close cooperation should be maintained between the teacher and the radio station offering the desired program.

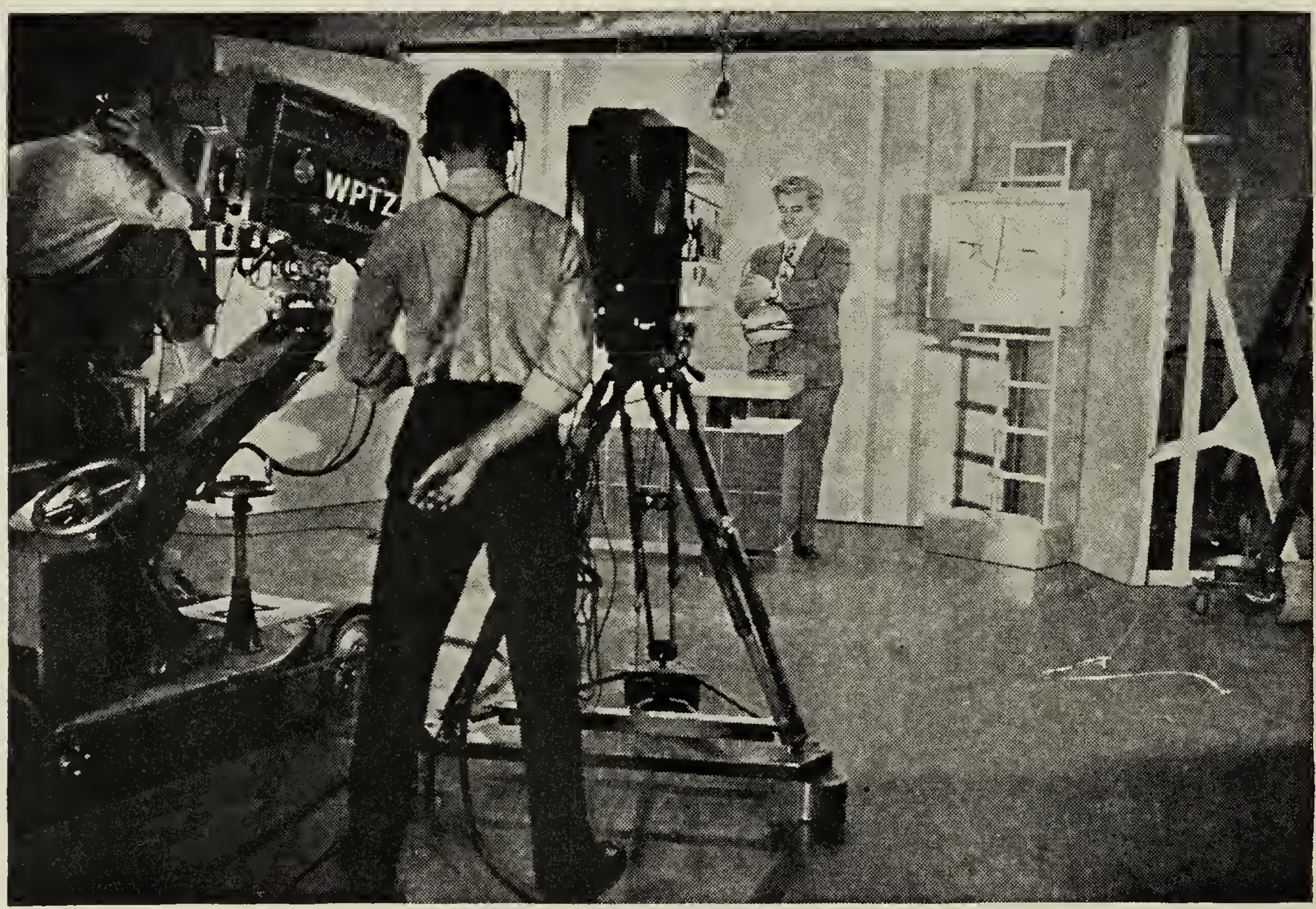


Fig. 41 Scene showing science telecast of Dr. Roy Marshall in his program "The Nature of Things" over station WPTZ. (*Courtesy of Philco Television Broadcasting Corporation.*)

Televising science dramas. Television combines sight with sound so that all science dramas must satisfy both the eye and the ear. This means that *action* must be present which is not achieved solely in the use of a set of gadgets for demonstration purposes. Thus television accentuates all the problems present in the radio drama and adds new ones besides. *Routine* is the key word since there cannot be any "retakes" and everything must be right the first time.

A discussion of the rehearsal factors is presented here. This should help the teacher appreciate and use television programs in classes. It should also facilitate the production of a drama to be telecast, by the science teacher, when this opportunity is afforded.

(1) A well-advanced rehearsal is held for the information of the director and the instruction of the cameramen. They must know the sequence of events in order to adhere to a close routine.
(2) A "dry run" is made at the studio using all the equipment and effects needed. This is a talk-through sequence that affords opportunity for discussing any special problems that come up.
(3) The camera rehearsal is generally staged next, so that the director can make any changes in the setting or lighting for camera angle views. The action is carried out just as if the studio were "on the air."
(4) The final rehearsal is then taken beginning with the introductory titles but with the commercials blocked out. Everything transpires "on time" here by the cueing signals from the director.
(5) When the program is being telecast the participants must be prepared to watch the stage manager without seeming to do so. They must be alert to the red lights on the camera (indicating that the camera is "on the air") but turn away when the lights go off and face the lens of a camera where the red lights have appeared.
(6) The participants must exhibit genuine interest in what they are doing, must wheedle, cajole, persuade and *prove that science is fun.*

Teachers who are taking part in television science dramas will find it necessary for holding audience-interest, to supplement the program with various gadgets and pieces of equipment. In this connection there are several suggestions for the designed materials to be telecast. These are:

(1) All pictures should be mounted on stiff cardboard or cards.
(2) Background scenery or other pieces to be shown should be painted at the studio or in the school under the advice of the director of the television station. In this way the "mock-up" will be a better representation of the actual conditions.
(3) Colors do not affect the television screens like they affect the eye. It would be well to consult the station director about what colors to use for best results in make-up, costumes, and scenery.
(4) Diagrams and equations can be drawn quickly and crudely on a pad of newsprint on a steady easel.
(5) Mechanical and chemical set-ups should be checked thoroughly to prevent failure.

The pageant. In this form of dramatic aid a procession of historical scenes with the characters in costume is portrayed.

The pantomine. This is a play in which there is merely acting.

No words are spoken during the action. The imagination is given full swing because ideas are conveyed by action alone.

The individuals in the pantomine should rehearse until they can actually "feel the part." They should not convey mis-meanings or misinterpretations to the audience. It is not sufficient for the individuals to act as automatons even if the action is fairly automatic at times. There is tense drama, for example, as a surgeon saves a life on the operating table, while few words, if any, are spoken. Yet much action is carried out on the part of the assisting doctors and nurses. Visit a clinic and watch in silence the pantomine of modern surgery and imagine that the person under the ether is a loved one or a close friend. There is little lack of "feel" of each person's part in the operating room.

Science is a moving and vital study. Therefore, have the characters in the pantomine make full use of bodily actions such as motions of arms and legs or facial expressions. For ideas, observe the pantomine put on by the advertising agencies using lighted billboards with turning wheels, on a picture of an automobile, or a child at a table eating cereal from a bowl with flash of spoon and arm movement, or a soft drink *pouring* (by simulated lights) into a tumbler. Then apply such simple actions to the pantomine in question but have each individual *live* the part!

The tableau. The tableau is a picture-like scene represented by one or more silent and motionless persons in proper attitude and costume, often with suitable accessories.

An example of a tableau presented in a high school in New Jersey during an assembly period is as follows:

THE ADVANCEMENT OF MEDICAL SCIENCES THROUGH THE AGES

Part I. Primitive Practices in Medicine
Sketch: The Medicine Doctor as shown by the Indians.
Part II. The Transitional Period
Tableau: Dining Scene in Ancient Castle showing unsanitary conditions of the time.
Part III. A New World is Discovered
Play: Scenes from the life of Pasteur
Part IV. Modern Medicine
Tableau: The Nurse (Florence Nightingale) and Doctor at work.

The program took forty-five minutes, allowing a few minutes for the change of stage equipment between the parts. Each teacher in the science department supervised one of the four parts, both directing and equipping the students. Students assisted in the costume making, which did not entail much expense.

The puppet show. The puppet show is a small scale stage on which miniature figures (marionettes) are moved by means of strings or wires to each position desired. This is a popular form of dramatic aid. The puppet show requires a great deal of preparation but it is generally very effective. Students in the art department can make the puppets and conduct the show. The puppet show is generally used in the elementary school but is just as effective in the secondary school.

The proper selection of the cast of characters is necessary. A good story or plot may literally be ruined by a poor cast of characters. The teacher should select the right student for each part to be played. It is best to have one or two alternates for each part in the dramatic aid. A double cast will secure more interest, will present wider values, and will provide experience for future dramatic presentations.

The properties and settings can be obtained through the coöperation of the faculty. Other departments may assist and the students will value the dramatic aid more if they are allowed to assist in the actual construction work. Much knowledge can be gained by the student when assisting in this way.

Finally the rehearsal will be complete as a unit if the other departments assist. The dances are often supervised by the physical education department. The costumes may be made by the home economics department. Stage settings are usually handled by the manual training department. If historical scenes are to be presented, the history department may assist. Lighting and projection apparatus can be directed by the science department. Songs may be supervised by the music teacher. Tickets and seating may be handled by the mathematics department. If the various departments will coöperate, a better dramatization may be produced.

The following is an example of the use of puppetry in science and is a puppet play written by one of the authors and presented as an Arbor Day Program in the auditorium of a high school in New Jersey:

A LESSON IN FOREST CONSERVATION

1. *Scenes:*
    - Scene #1: Natural forest background painting by a student. Dirt and sod on stage.
    - Scene #2: Same as #1 with addition of a campfire (lighted) and subdued lighting for night scene. Tent shown.
    - Scene #3: Background changed to show a forest destroyed by fire, charred trees, etc. Burned material on stage. Odor of burning wood.
    - Scene #4: Use #1 background again, and tent, with campfire extinguished. Increased lighting. Early morning.
2. *Cast of Characters:*
    - Puppet #1 (P–1), known as Bill (a doctor)
    - Puppet #2 (P–2), known as Jim (a business man)
    - Puppet #3 (P–3), known as Harry (a lawyer)
    - Puppet #4 (G. W.), known as Game Warden
3. *Costumes:*
    Puppets Nos. 1, 2, and 3 were dressed in green Robin Hood type suits. Game Warden dressed in brown uniform.

SCENE #1

Curtain opens on natural forest scene, with no puppets on the stage. P–1, BILL, comes on the stage, points to the forest and recites—

P–1, BILL. "This is the forest primeval. The murmuring pines and the hemlocks
Bearded with moss, and in garments green, indistinct in the twilight,
Stand like Druids of eld . . . "

[Enter P–2, JIM, as P–1 sits down. Imitation of sounds of birds.]

P–2, JIM. Where shall I place our camping equipment, Bill? You sure have picked a nice cool spot for us to camp on during the week.

P–1, BILL. Yes, that is the beauty of the forest. One can come here for solitude, for rest, and for peace of mind. A bit of heaven, as one might say, placed here by nature for us to enjoy.

P–2, JIM, That's right, Bill. I have been looking forward to this camping trip all week so that I, too, might have a chance to get away from the cares of the business world. A visit to the woods sure peps up a person. I expect to go home a new man, full of zest and vigor from the experiences gained here.

P–1, BILL. Well, Jim, I'm glad you feel that way, because we are here to rest, hunt, and enjoy nature. It's getting late—suppose we start to unpack our tent? By the way, is Harry bringing the food?

[They start to unpack. HARRY, P–3, comes in with packages under one arm and wooden gun under the other.]

P–3, HARRY. Well, fellows, here's the food. Looks like you fellows are starting to enjoy the woods by pitching the tent. I think I'll stroll around a while and see if I can sight some wild animals.

P–1, P–2 (*in unison*). O. K., Harry.

P–2, JIM. Don't be too long—supper will soon be ready. We will call you, so don't go too far.

[HARRY, P–3, goes sauntering off stage. Curtain closes.]

SCENE #2

The tent is set up on the stage, campfire built and lighted. P–2, JIM, is holding pan over fire. P–1, BILL, stands near tent. Subdued lighting.

P–2, JIM. Bill, give Harry a call. The grub is ready.

[P–1, BILL goes to side stage and calls.]

P–1, BILL. Harry! Harry! Supper is ready.

[He listens and P-2, HARRY, calls faintly (off stage).]

P–3, HARRY. I'm coming boys!

[P–1, BILL, walks over to the lighted campfire and sits down.]

P–2, JIM. Boy, the food smells good! Being out in this atmosphere sure gives me an appetite!

P–1, BILL. I think so, too. One can come to the woods and work up an appetite for some real food. While at home my appetite isn't as real as the one I get out here. This cooking with nature's implements gives a camper a real thrill.

P–3, HARRY *(entering, goes towards them)*. Say, fellows, this is a very pretty spot (*sits*). I'll tell you all about my short walk as soon as I satisfy my hunger for some of that crisp bacon and coffee.

[All three pretend to eat food. If possible rattle some tableware, such as forks and knives, or scrape an aluminum pan.]

P–1, BILL. Let's sing something, boys.

[P–3, HARRY, starts backstage, with guitar, mandolin, or mouth, organ]

P–3, HARRY and rest. "Oh give me a home,
Where the buffalo roam,
Where the deer and the antelope play—"
(full song).

P–2, JIM. That's fine, fellows. Look up at those tall trees, like giants, towering against a background of silver. Somehow I feel as though there is more to life than sitting at a desk giving orders. Just think how nature is giving us orders to enjoy her beauty, her freedom, her spirit!

P–1, BILL. Yes, you are a successful business man at home, but nature does not ask us who we are. Look at me, a doctor, busy every day in the office, treating patients with all sorts of ills, dabbing antiseptics here and there and trying to relieve mankind of its numerous ailments. Then to the hospital late at night, while all are asleep, and operating amid ether fumes and other anesthetics. Then home in the early morning hours to rest—not a deep sleep of the peaceful kind, but that of restlessness after hard labor. And here I sit, far from the ills and pains of the world, enjoying myself, breathing in the purified air and opening my soul to nature's wonders. What a heritage can be found in the woods! Oh, if we only would appreciate them more.

P–3, HARRY. And I, too, a lawyer—standing in the court each week, arguing and pitting my brain against the most skillful of my profession; delving into some old musty law book for this or that ancient law and all the time forgetting that nature's laws are far greater than any of man's substitutes. You are right, Bill, nature doesn't ask us who we are but *what* we are.

P–1, BILL. I think so, too. Well fellows, I'm getting tired. Guess I'll turn in. Are you fellows sleepy, too?

P–2, P–3 (*in unison*). You bet.

[They turn in. After a few minutes there is heard some slight snoring. The campfire spreads out and sets fire to the trees. This is done by pulling the red light toward the back of the stage, and throwing red lights on the scenery. P–1, BILL, appears to wake up and sees the fire.]

P–1, BILL (*yelling*). Forest fire, boys. Let's go get help! (*They yell for help.*)

[The puppets move hurriedly off stage and the curtain is drawn.]

SCENE #3

This scene shows a destroyed forest in the background. Trees are charred and black. White light is thrown on stage. The three puppets come sauntering in.

P–1, BILL. Well, fellows, here's our old camping site. Just look at it now—no longer a beautiful place to camp. No shelter, no foliage, no singing birds. Can it be possible that a single match could cause so much trouble?

P–2, JIM. Yes, Bill, it is possible. If we had been more careful we would have put out the campfire before it had a chance to spread and caused so much damage. It was pure carelessness on our part and we are to blame. Here we were, enjoying ourselves to the fullest but not taking care of what we had. Now we do not have it to enjoy.

P–3, HARRY. Well, I feel that way, too, fellows. We are all guilty of a crime far greater than we can realize. No longer will we be able to come here and enjoy what we had.

[The GAME WARDEN enters from the side of the stage.]

G. W., GAME WARDEN. Sorry, boys, but I must arrest you in the name of the law for causing this forest fire. All of you know that the penalty is ten years in jail at hard labor.

[GAME WARDEN starts to lead them off stage. As they go off, P–2, JIM, goes last, but fights the GAME WARDEN all the way off the stage. Curtain closes.]

SCENE 4

Return to original scene #1, natural forest scene. Bright light on stage. Puppets are still sleeping on stage near campfire. P–2, JIM, is in a half sitting position, waving his arms wildly in the air, and yelling:

P–2, JIM. Let me go, Warden. I didn't mean to do it, honest—honest, I didn't mean to do it . . . (*loud*).

[All the puppets sit up quickly as if startled.]

P–1, P–3, HARRY and BILL. What's the matter, Jim! Speak, man, speak!

P–2, JIM. Oh boys, I had the most terrible dream of all. I dreamt that we carelessly left the campfire burning last night and it set fire to these beautiful woods and destroyed them. Then the game warden came along and arrested us for causing the forest fire. Gee, it was awful! This place certainly looked a mess.

P–3, HARRY. Well, Jim, I guess you did have a bad dream and it would have been terrible if it had actually been true. Your dream has taught me a good lesson.

P–1, BILL. Me, too, Jim!

P–3, HARRY. I guess we never value what we have until we lose it. Tell you what, boys—when I go home to my law office, I'm going to instruct all my members of the law firm in the principles of forest protection. And I'm going to line up with the state in its drive against such carelessness and the apprehension of such criminals. Believe me, they'll be prosecuted too!

P–1, BILL. You can count on me too, Harry. The forest fire is one ill that I, as a doctor, cannot cure. I know what it means to human beings when they get burned by fire and so I can imagine the loss we suffer through such carelessness. I'm going to tell my patients who need a rest to come here and I personally will instruct them in the methods of forest fire prevention.

P–2, JIM. Hey—don't leave me out of this, for I, too, have learned a lesson. And you may be sure my business associates will be trained that way also. It's daylight now, so let's get up and enjoy the beauties of these woods before we leave.

[The puppets arise and stroll off stage. They point to the natural forest background. The curtain is drawn.]

Finis

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QUESTIONS AND EXERCISES

1. In what ways are science wall charts effective teaching aids?
2. What is the teacher's part in planning a broadcast or telecast school program?
3. Where can courses in radio and television studio techniques be pursued?
4. How do televised science programs differ from radio science programs?
5. Compare the effectiveness of science cartoons with other teaching aids.
6. How would you organize and present a science tableau?
7. What departments in your school could assist you in presenting a play stressing fire prevention? Give their responsibilities.
8. How could puppets be used to teach safety?

PROJECTS

1. Make a drawing of a seashore scene or a typical cell, using white "stipple-board." (A protective and useful surface covering in blue, yellow or black, known as Zip-O-Tone, can be obtained from F. Weber Co., Phila., Pa.)
2. Design a science cartoon or cartoon series using regular drawing materials.

3. Completely paint one side of an 8 inch by 10 inch piece of stiff white "scratch board" using India ink. Allow this to dry and then trace with a stylus the design for a science poster or graph.
4. Find out how to block-print with linoleum and make some scientific prints.
5. Secure some handicraft materials catalogs from various Arts and Crafts stores. Investigate the use of protective coatings (spray, film, sheet) for posters and drawings.
6. Outline a program for a science tableau or puppet play to be presented in school or on the radio and television.
7. Visit a radio or television station and find out how a teacher can assist the director in preparing school programs.

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Chapter 19

MICROSCOPES AND MICROPROJECTORS

The light microscope has been an important tool of scientists for a long time. It is also an important tool in teaching various phases of science. If a science teacher has only one microscope at his disposal he should consider the advantages of obtaining a microprojector or a euscope which may be used with any standard laboratory microscope. The advantages of these attachments are described later in this chapter.

In recent years a new kind of microscope, the electron microscope, has been invented. The electron microscope is not yet in use in our public schools, however, science teachers should be familiar with this new tool of science. Great discoveries have already been made with it and no doubt even greater discoveries will be made in the future.

The Light Microscope[1]

The light microscope is a delicate and expensive precision instrument. It requires careful handling and skillful manipulation.

Care of the microscope.

(1) In removing the microscope from the case, grasp the instrument by the curved frame. Carry it in an *upright* position and do not let it strike any hard object.
(2) Make any adjustment of the parts slowly, holding the frame while the parts are being moved, except when focusing.

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[1] The authors are indebted to Professor James Meyers and Professor Malcolm E. Little, both of New York University, for their permission to use the materials on the microscope from their laboratory outlines in college biology.

(3) Do not use any rough or dusty paper or cloth on any parts of the instrument. Always use lens paper in cleaning the lenses.

(4) In replacing the instrument in the case, carry as before; and be certain that the bottom lenses (*the objectives*) are turned so that neither is pointed directly downward.

Structure of the microscope.

(1) The iron framework is divided arbitrarily into the *arm,* the upright portion, and the *base,* the portion upon which it rests.

(2) The upright, tubular structure is known as the *body tube.* This tube holds the lenses and is an essential part of the instrument.

(3) Fitted into the top of the body tube is the removable *ocular,* or *eyepiece,* which holds the lens nearest to the eye.

(4) At the basal part of the body tube is the revolving *nosepiece.* This holds two or more removable small tubes which hold the lenses nearest to the objects. These tubes (including the lenses) are called the *objectives.* The objectives are two (or more) types. In the student's microscope one is a *low-power* objective, and the other is a *high-power.* The low-power usually magnifies ten times (10 ×), and the high-power forty-three times (43 ×). This is usually marked on the objective, together with the distance from the object at which the objective comes into focus. Objectives with higher magnification used in more detailed studies are usually known as "oil immersion." The nosepiece may be revolved so that either objective points directly at the object on the slide. The correct position is indicated by a slight click as the objective reaches the correct position. The low-power objective is shorter and focuses farther from the object. A little practice and observation will readily show the difference.

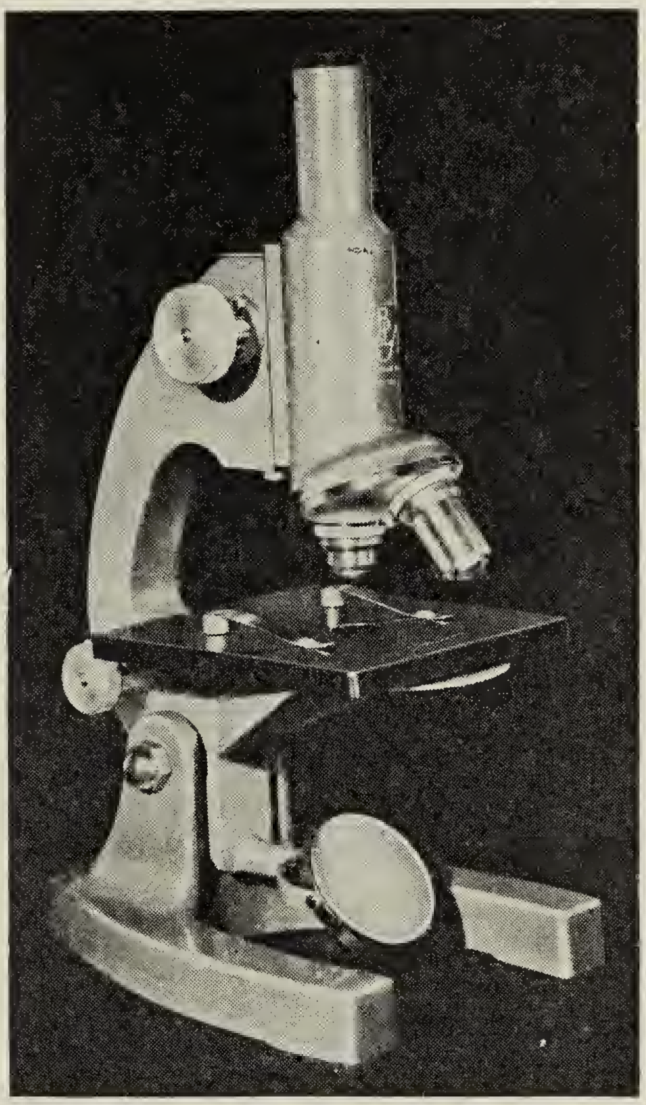

Fig. 42 A compound microscope. (*Bausch and Lomb Optical Co.*)

The *oculars* (*eyepiece*) also differ in magnifying power either 5 ×, 10 ×, or 15 ×. To determine the magnification of an object under the microscope *multiply* objective number by the ocular number. That is, a 45 × objective with a 10 × ocular gives 450 × magnification.

(5) Below the nosepiece is the horizontal stage. This is attached to the arm, and is usually movable (but it is not to be disturbed by the student). The object to be studied is placed on the stage, directly under the objective. Such objects should always be placed on a clear glass slide. The opening in the stage, through which the light is reflected, indicates the proper position for the object.

(6) The space below the stage is called the substage area. In this region several structures may be found.

(a) The *condenser* is a lens which helps in focusing the rays of light on the object. This may be moved up or down with the turn of the screw on the student's left when the microscope is in position with the arm of the microscope toward the student's body.

(b) The *diaphragm* is attached to the movable condenser. This opens and closes and admits or shuts out light as it enters the condenser. Most students prefer to control the amount of light with the condenser rather than the diaphragm. The diaphragm is controlled by the small lever toward the front of the condenser.

(c) The *mirror* is one of the most important parts of a microscope. Proper light is *usually as important* as proper magnification. The mirror has two faces, one flat for use with strong light; the other concave for use with dimmer light. Most errors in microscope use come from a lack of understanding of *lighting*. Microscope studies are made with light reflected from the mirror. Recall that the light rays leave a mirror at the same angle at which they strike the mirror (*i.e.*, the angle of incidence equals the angle of reflection). The mirror may be rotated in two directions. *Keep Experimenting* with the mirror until you can understand the principle and practice of the reflection of light in a microscope.

(7) Focus adjustment. On the upper part of the frame will be found two adjustment screws which raise and lower the body tube. The larger is called the "coarse adjustment" and will raise and lower the body tube a relatively large distance by a single revolution. The smaller or "fine adjustment" moves the body tube an almost imperceptible distance. In focusing an object the fine adjustment is used to complete the process by bringing the object into more delicate focus. In this way the latter is used to supplement the coarse adjustment screw and thus to bring out the finer details of structure.

Use of the microscope.

(1) In securing the microscope lift the instrument by the arm and then balance with the base in the palm of the other hand. Never tilt the microscope.

(2) Place upon the desk with the arm toward the edge of the desk and do not tilt the stage.

(3) Turn the nosepiece until the low-power objective is in line with the body tube and ocular.

(4) By means of the mirror focus the light rays up from the concave surface through the condenser. By placing the eye at the ocular you should be able to see the light field, if the objective is in alignment.

(5) NOTE carefully if there are any defects or dirt marks on any of the lenses. If so determine where they are located.

  (a) Revolve the ocular while looking through same. If the mark moves then it is located in this part.

  (b) Change from low to high-power objective. If the dirt disappears then the low-power objective needs cleaning.

  (c) If there is a slide under the microscope, focus it and then move it from side to side. If the mark moves then the slide should be cleaned.

  (d) If none of these methods locate the speck then clean condenser and mirror.

In cleaning all of the lenses always be sure to use lens paper. *Always wipe the slide before using.*

(6) Place the slide under the objective with the material to be studied directly over the hole in the stage. Focus the light up through the stage. Turn down the low-power objective as close to the slide as possible without touching it. Then with the coarse adjustment turn the body tube slowly upward until the slide is in focus. In focusing it is often advisable to move the slide gently while raising the objective. When the slide is in focus it will be noticed that the slightest defects in the glass are noticeable. This will serve as a guide since at first it is difficult to place material to be studied directly in the field of vision. After it has been located in the center of the low-power field then the high-power objective may be revolved into place. When this has been done it will be advisable to increase the amount of light since higher magnification requires more light. This adjustment may be made by opening the diaphragm, or raising the condenser, or by a combination of both. Then proceed as with the low-power, first lowering the objective as near the slide as possible and then raising it. *Never focus downward.*

(7) In using the microscope it will be advisable to keep both eyes open and thus to relieve unnecessary strain. This will be difficult at first, but by practice may be formed into a habit.

CAUTIONS

Keep both eyes open.

When carrying a microscope do so by balancing the base on one hand and holding the arm with the other.

Clean lenses with lens paper only.

Do not attempt to take the microscope apart.

Always focus upward.

Always focus with the low-power first and then with the high.

The efficiency of the microscope is dependent upon the efficiency of the user.

The light must be carefully regulated in order that the object may be seen clearly.

Preparation of Microscope Slides

As stated in the exercise of the microscope, any object to be studied under the microscope is mounted on a glass slide. Many of these slides are permanent preparations or "prepared slides"; while others are made in the laboratory for immediate use and are temporary in nature. The latter are usually known as "wet mounts."

Making a permanent mount. The technique of making permanent preparations is usually complicated, and is not a part of the biology laboratory work. The student, however, should understand the nature of these mounts.

(1) A permanent preparation involves covering the object with a very thin glass "cover slip" which protects the object from loss and crushing.

(2) The cover slip must be firmly attached to the slide with a transparent material. For this purpose a resin, Canada balsam, is used. This substance is soluble in xylene (one of the benzene group of hydrocarbons) and can be made to any consistency. In addition to transparency, the resin has approximately the same refractile index as the glass slide, and causes little distortion of the light rays as they pass through.

(3) Any *dry* small object is mounted by:
  (a) Placing the small object on a glass slide;
  (b) Covering with fairly thin balsam (in solution); and
  (c) Carefully placing a cover slip on the top. Care in placing the

cover slip is *always necessary* to prevent air bubbles from forming under the slip. Air causes a great distortion of the light rays, and destroys the value of the slide.

(4) Most biological specimens used for study are not dry, for protoplasm is a colloidal suspension. Water and xylene are not miscible, therefore, the object must be dehydrated. This is done as follows:
  (a) The protoplasm is killed with strong poisons to prevent distortion of the object.
  (b) The water is removed with alcohol—the object being carried through a progressive series of alcohol until they are in almost pure grain alcohol ("absolute alcohol" which is purer than the 95 per cent alcohol).
  (c) As pure alcohol and xylene are miscible, the object is then immersed in xylene to remove the alcohol, and then placed on the slide and mounted.

Preparation of sections for study. Biological materials are frequently too large for mounting on a slide. In this case the specimen or a fragment of it must be sectioned, or cut into thin slices. These slices must be sufficiently thin to be transparent. To cut the materials thin it is necessary to have the materials firm and yet soft enough for the knife to cut smoothly. Several substances are used for this purpose, but paraffin is the most widely used.

Before the sectioning begins, every cell of the organism or fragment must be thoroughly filled with paraffin. The process is briefly as follows:

(1) The fragment (tissue or organ) is "killed." The cells are then said to be "fixed."
(2) After killing, the fragment is carried through the alcohols for dehydration. After removing the water, the cells are then placed in xylene, as in making total amounts of small objects.
(3) Xylene is a solvent not only of resin, but of paraffin. Therefore, the tissue is placed in a vial or dish of xylene, and melted paraffin is added. From this mixture the specimen is placed in more paraffin until all the xylene is removed.
(4) After the melted paraffin penetrates all the cells of the tissue, the cells are said to be "completely infiltrated." It should be understood that paraffin of a fairly low melting point is used, so that the tissue will not be baked in the process.
(5) The tissue is now embodied in a block of paraffin and can be cut. The simplest cutting device is a heavy sharp knife. This is "freehand" sectioning, and is quite accurate in the hands of experts.

(6) For very thin sections, and for perfect accuracy in getting the slices the same thickness, an instrument called a *microtome* is used. This instrument is so geared that it is possible to cut out sections 1/25,000 part of an inch in thickness. The average laboratory slide material is cut about 1/2,500 part of an inch in thickness.

Preparation of wet mounts. In biological work much of the material is living, and must be handled carefully. The living organism or cells *must be kept* moist. For fresh water organisms, with cells which need not be kept alive for more than a few minutes, tap water is used. For cells which are taken from larger plants and animals, the fluid which is placed around them must be similar to the body fluids of the organism. Otherwise the cells rapidly degenerate. The fluids which are in balance with the body fluids are called "physiological solutions," and such solutions are made by adding various salts to the water. If nutrient substances are added also, the cells may be kept alive indefinitely (provided temperature and acid concentration are kept constant and suitable to the cells).

In the preparation of a wet mount always keep in mind that the use of the microscope is dependent upon the passage of light rays through the material on the slide. If the object is too dense, the light will not pass through and the details will not be visible. In some cases this may be remedied by letting the light fall directly on the surface of the object (that is, not reflected from the mirror). One thus sees the object with the light directly reflected from the surface. This method is worthless except for surface study.

Before making a mount, make sure that all the glassware, including the slides, cover slips, pipettes, and other apparatus are *clean.* If not, the visibility will be lowered; and if any chemicals are on the apparatus, the specimen may be killed.

CAUTIONS

(1) Always use a cover slip when using a compound microscope.

(2) Always focus first with the low-power, and then turn to high. Use the fine adjustment, first turning the screw counterclockwise. (This brings the objective away from the slide.) If the object does not come into focus, lower the fine adjustment *slowly* over the object. *Make sure that the objective is neither dirty nor wet. Do not* let the objective hit the slide, or the objective may be scratched.

(3) Remember that a microscope can be focused at infinitely minute distances. In other words, a section of tissue only 1/25,000 of an inch in thickness is not seen all at once under the high-power. You can focus at the upper surface of the section, in the middle regions, or at the lower surface.

(4) In thin sections most of the cells of the tissue will have been cut, so that all the cellular structures will be present in relatively few of the visible cells. In this case a composite picture may be made by studying adjoining cells.

The Microprojector

The microprojector is designed to project highly magnified images of tiny things such as bacteria, protozoans, and algae to the screen. This projector makes it possible for microscopic objects to be seen by the entire class and it enables the teacher to point out the features of special importance.

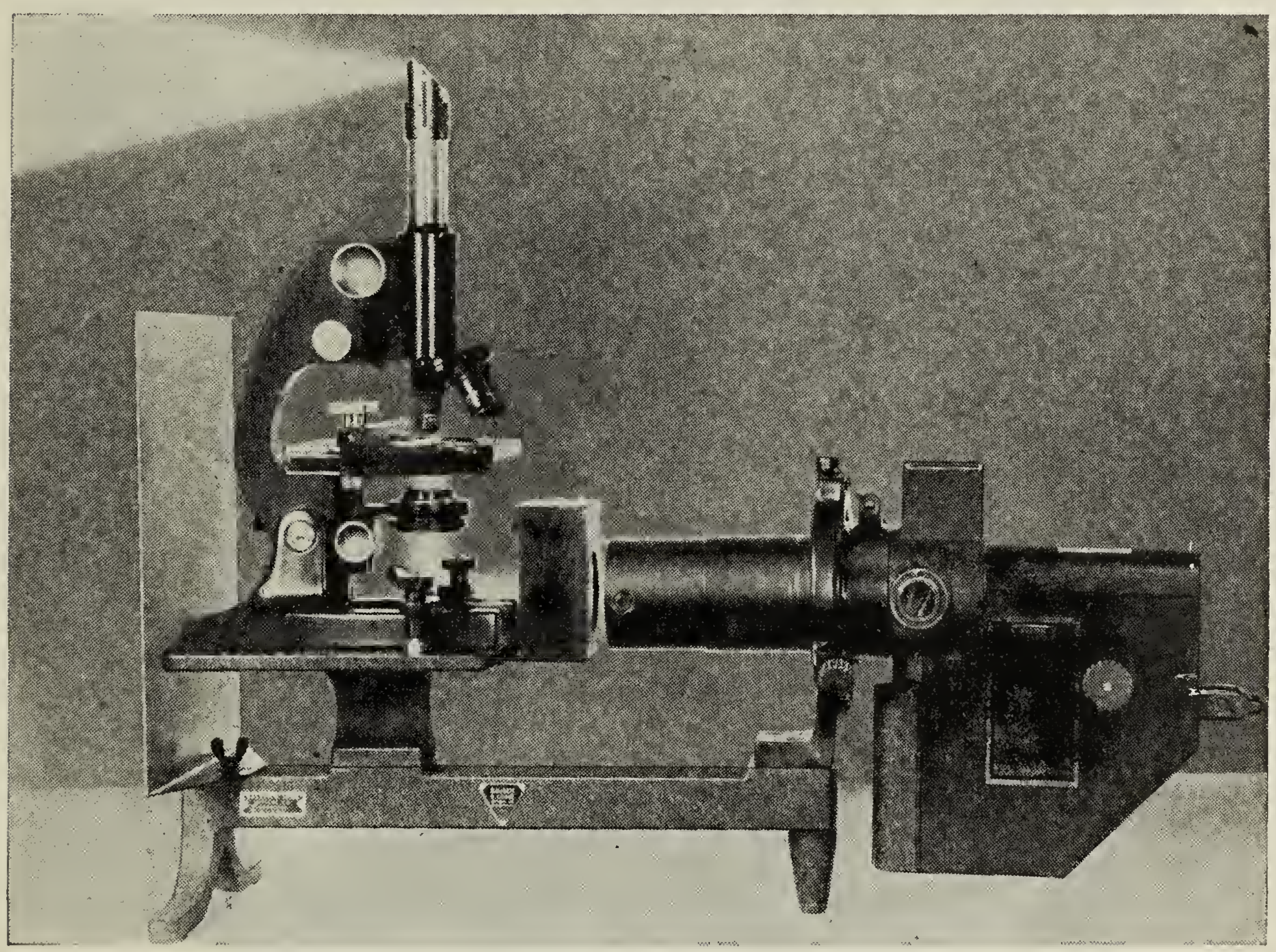

Fig. 43 A microprojector. (*Bausch and Lomb Optical Co.*)

If the teacher owns a reasonably recent microscope, a microprojector designed for use with the microscope should be purchased.

In the most efficient microprojectors, illumination is provided by means of a clockwise feed arc lamp. The arc lamp operates in connection with a rheostat on either direct or alternating current. However, direct current seems to give better results than alternating current.

Schools that wish to project living material, such as a live amoeba or paramecium, to the screen should purchase a microprojector outfit that has a water cell. The water cell protects the specimens from the heat of the light beam.

Microprojectors are relatively easy to operate. Detailed directions for their use are furnished with the projector by the manufacturer.

The Euscope

The euscope is an apparatus that is used with any standard laboratory microscope. It serves three purposes:

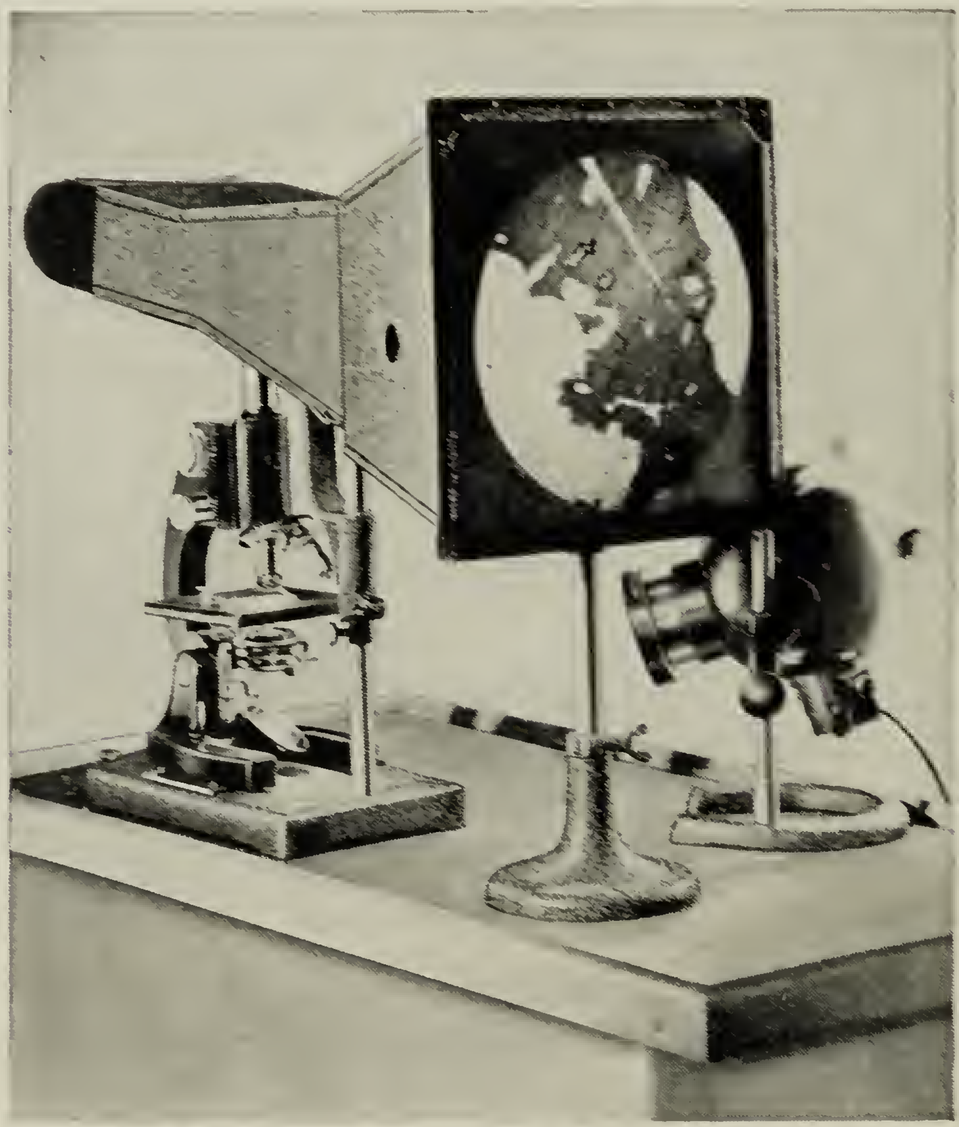

Fig. 44 A euscope. (*Bausch and Lomb Optical Co.*)

(1) It permits individual observation of microscopic objects with both eyes. It fits closely over the eyepiece of the microscope and contains a prism which throws the image of a magnified object on a ground glass screen. It nearly doubles the magnification given by

the microscope, and this tends to make work with the microscope less fatiguing.

(2) The euscope may be used for microprojection work. A special viewing attachment is placed over the end of the euscope for this purpose. This makes the euscope very valuable for work with small groups of students. Students are able to observe the magnified objects while the teacher manipulates the microscope and points out the features to be observed.

(3) The euscope may be used for photomicrography. A special camera attachment which fits the euscope is necessary. The camera attachment converts the euscope into a photomocrographic camera for taking pictures of microscopic objects.

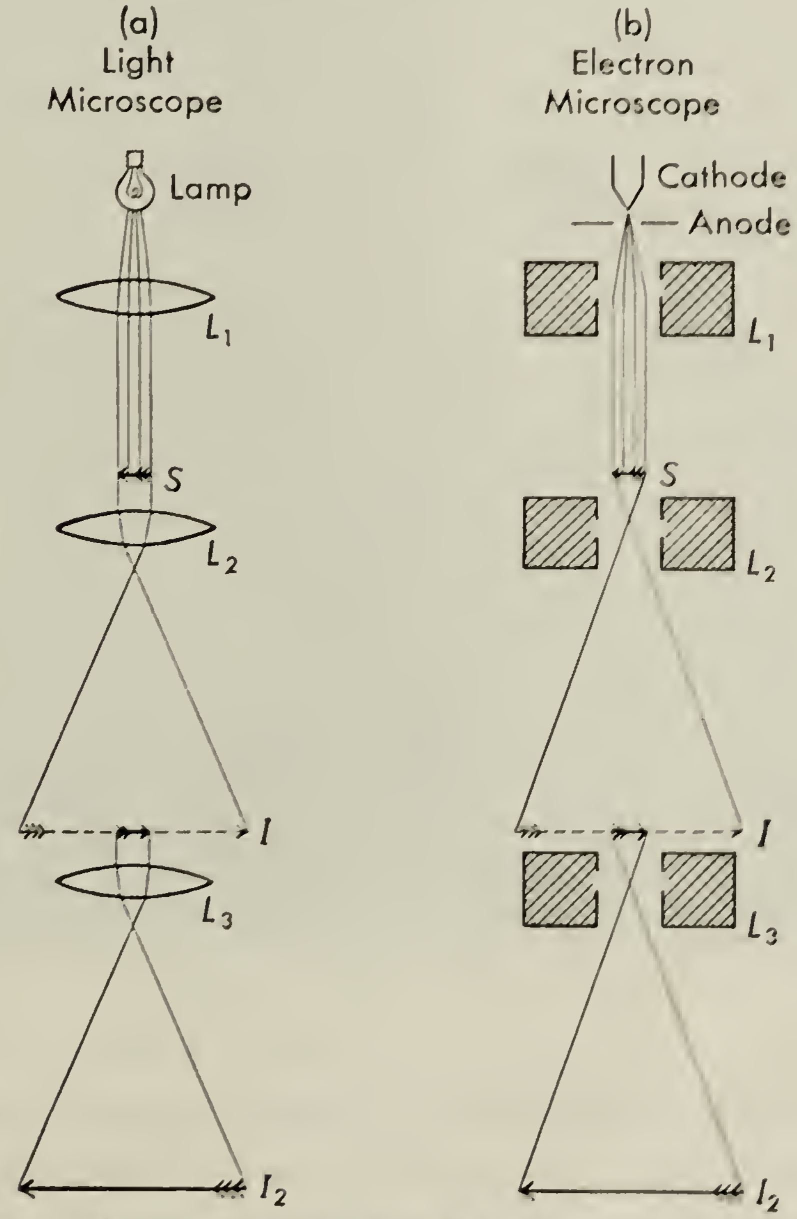

Fig. 45 Drawings showing the analogy between the light microscope and the electron microscope. (*Radio Corporation of America.*)

The Electron Microscope

The electron microscope is a new kind of microscope. It employs a beam of electrons instead of light rays for obtaining higher resolving powers and much greater magnifications than those obtained with the light microscope. The light microscope is limited by the nature of light itself so that magnifications beyond 2000 times (2000 ×) do not show significant detail. The electron microscope is not so limited since the wave lengths associated with the electrons in the beam are of the order of one-millionth of the wavelengths of visible light. Thus the details in the image obtained in an electron microscope are much greater than the details obtained in the image of the light microscope at magnifications of about 2000 times (2000 ×) or more.

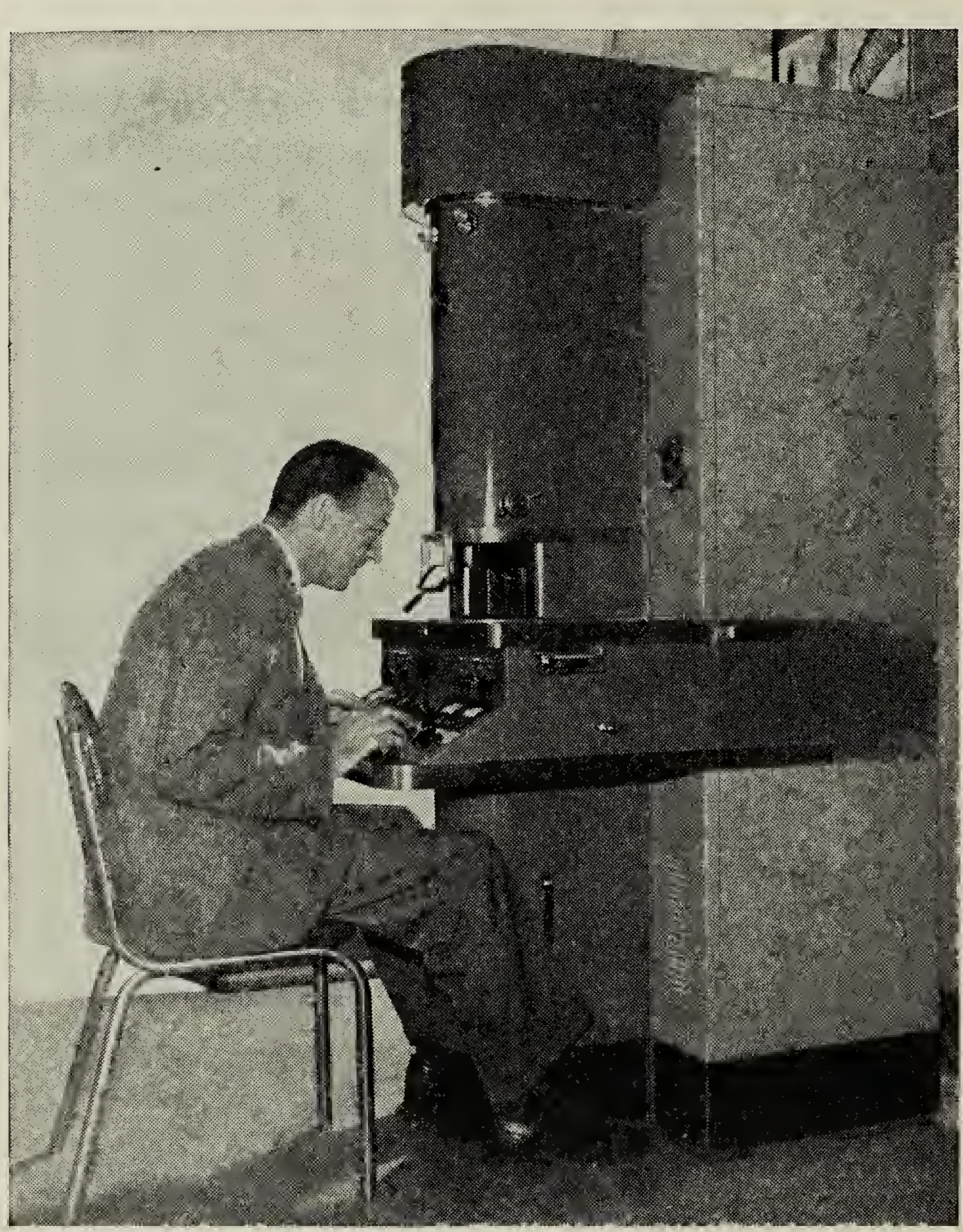

Fig. 46 The Universal Model electron microscope. (*Radio Corporation of America.*)

The electron microscope and the light microscope are similar in principle. The light microscope uses optical lenses for focusing light rays, whereas the electron microscope uses mostly magnetic or electrostatic "lenses" which are capable of focusing the electron beam. This similarity is shown in Figure 45. The image produced by the transmission type light microscope is seen directly by the eye, while the image produced by the electron microscope is seen on a fluorescent screen. Images produced by either of these instruments can be photographed and enlarged but the total enlargements possible with the electron microscope are much greater than those of the light microscope.

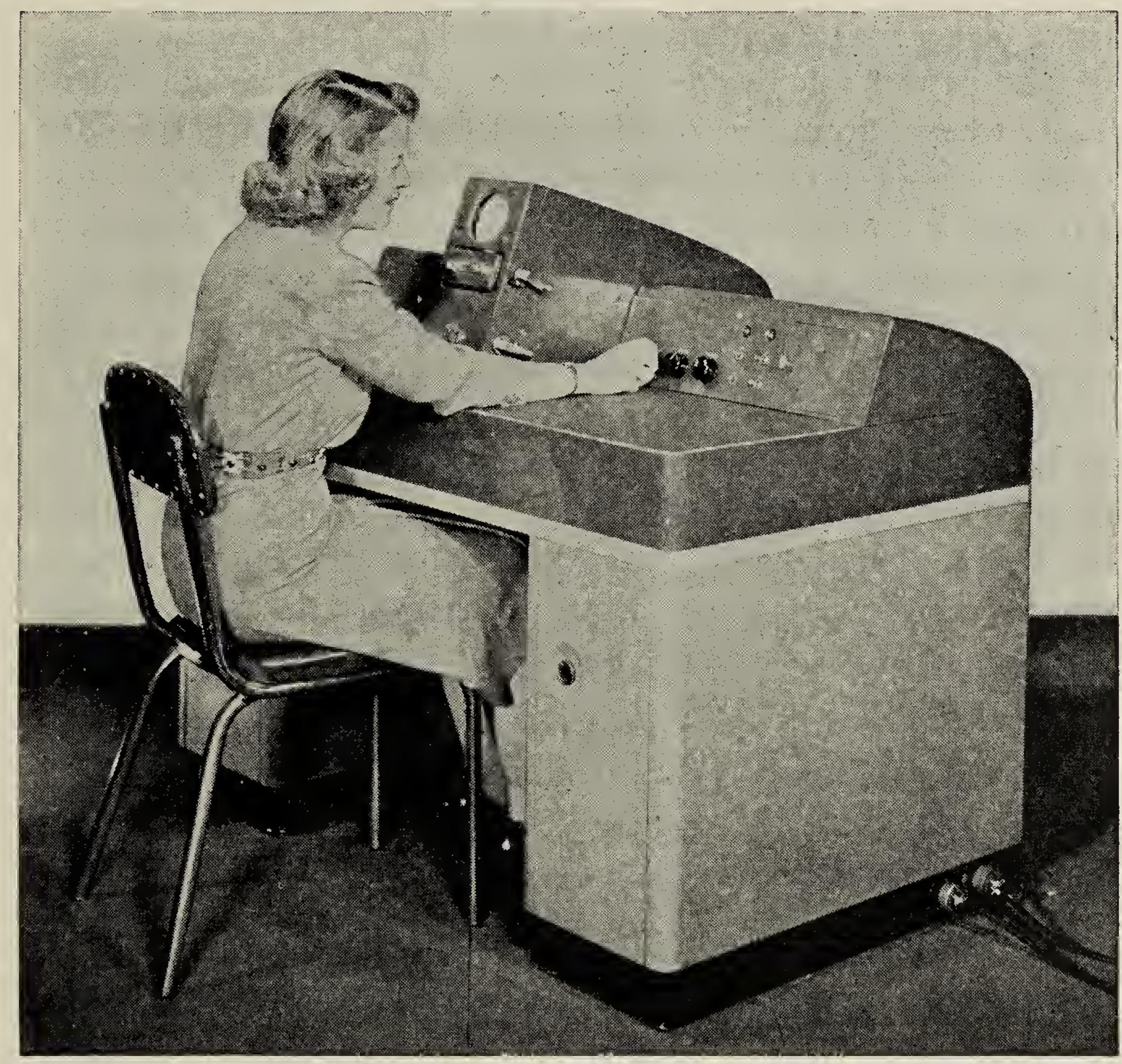

Fig. 47 The console model electron microscope. (*Radio Corporation of America.*)

The field of application of the electron microscope is quite wide. Two models of this instrument are available, depending on the magnification desired and whether it is needed for teaching, control work, or research work. The Console Model is popular for industrial applications in small laboratories, hospitals and schools since it is less expensive, lighter, and smaller than the Universal Model. Magnifications of from 500 × to 5000 ×, useful for teaching such subjects a biology, metallurgy, or bacteriology, can be obtained with the Console Model giving possible photographic enlargements up to about 100,000 diameters, depending on the subject material. The Universal Model is much larger, more expensive, and more flexible than the Console Model and is popular in research laboratories where higher magnifications (about 20,000 ×) are desired.

The electron microscope is useful for making stereoscopic micrographs where information on three dimensional structures is needed. Micrographs of surfaces of various materials as in metallurgy can be obtained for study or teaching by the so called "replica" method. In medicine and bacteriology, teaching with the electron microscope is outstanding for "shadow casting" investigations of bacteria, bacteriophage and viruses. A description of these techniques can be obtained from the references. In industry, the electron microscope is useful for particle size measurements of various chemicals, in studying fibre structure of textiles, and in studying foods such as the fat particles in homogenized milk. Many other teaching or research applications of this instrument are being made but new developments and refinements in the instrument itself will result as future requirements arise.

QUESTIONS AND PROBLEMS

1. In what phases of science teaching is a microscope necessary?
2. What are some advantages of the microprojector?
3. Compare the uses of a microprojector with the uses of a euscope.
4. How does an electron microscope differ from the more common light microscope?
5. What are the advantages of an electron microscope?
6. In what fields of science are great discoveries being made with the electron microscope?

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Hall, C. A., *How to Use the Microscope,* Macmillan Co., New York, 1935.
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Chapter 20

THE TELESCOPE[1]

Astronomy is an important area of science. There is a variety of evidence which indicates that both children and adults are keenly interested in heavenly bodies. Sometimes astronomy is neglected because of erroneous notions concerning the expense involved or lack of information concerning what may be done with a small instrument.

Expense is no reason for excluding the study of astronomy. The telescope is the only instrument needed, and it does not wear out. The cost of such an instrument is usually much less than the cost of equipment for teaching any other laboratory course. No housing or observatory is absolutely necessary. It should be remembered that an observatory is primarily a shelter for a permanently fixed instrument and hence is unnecessary if a portable model is used.

In considering expense, the question of whether the instrument should be a reflector or a refractor is sure to arise, as it is ordinarily possible to purchase a larger reflecting telescope for the same amount of money as a refracting telescope. There are, however, several advantages which have caused the refractor to remain the most popular type for educational situations, while the small-sized reflector remains preëminently the instrument of the amateur astronomer. The care required by the mirror, which must be resilvered at regular intervals, the awkward shape of the instrument and generally unattractive appearance, together with its optical limitations, has never enabled the reflector to gain favor in the educational field.

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[1] The authors are indebted to the Bausch and Lomb Optical Co. for their kind permission to use materials liberally from their publication, *Teaching with the Telescope* by E. S. Bissell.

The refractor on the other hand is easily portable in sizes having objectives as large as 4 inches.

Such an instrument presents an attractive appearance, requires nothing but ordinary care and treatment, and represents a permanent investment. It is possible to obtain such instruments in the standard sizes of 60 mm., 80 mm., and 102 mm. objectives. Telescopes of the latter size are considered large enough to warrant the equatorial mounting and can be had equipped with a permanent base, clockwork, hour circles, and all other necessary equipment. Such a telescope makes a fine observatory instrument for the small college or large city high school, at the modest price of about one thousand dollars. On the other hand it is possible to do good work with the small 60 mm. instrument.

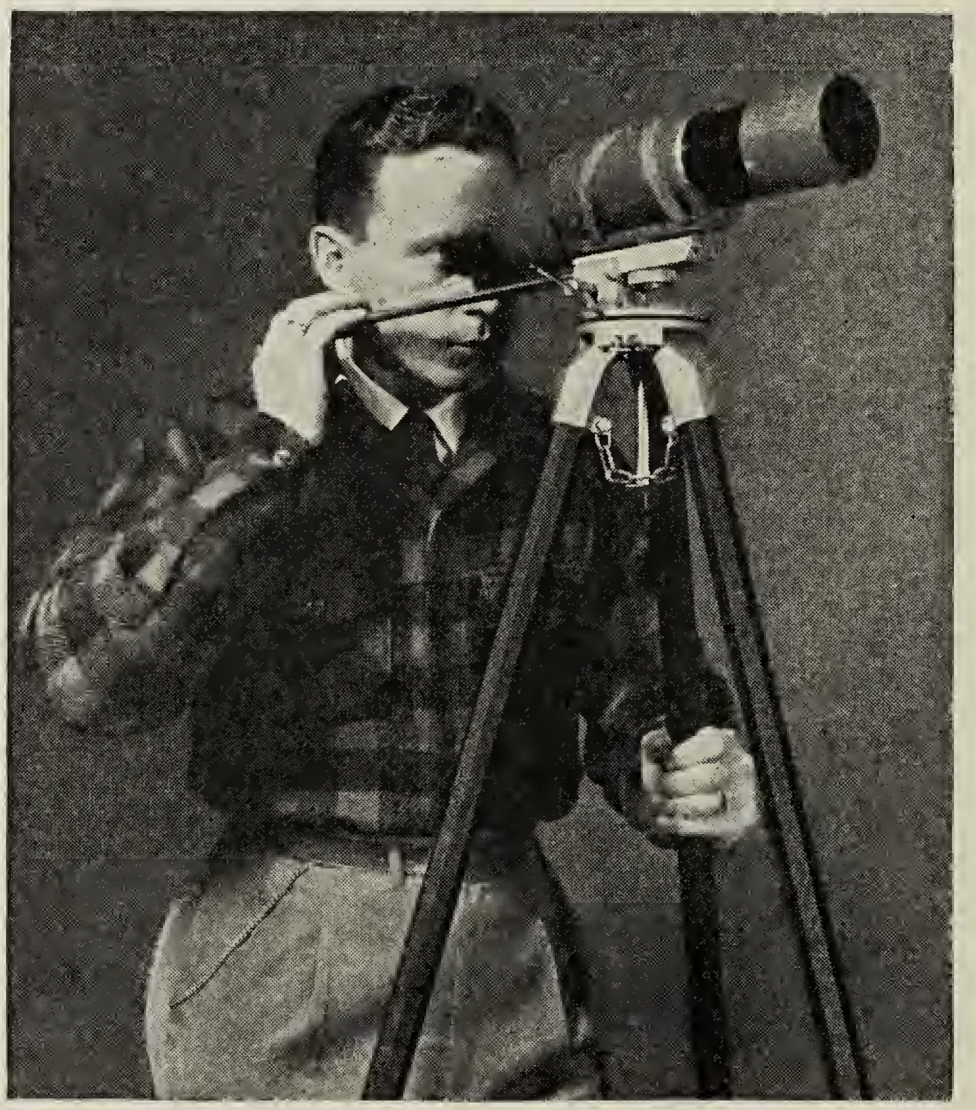

Fig. 48 A portable 60 mm telescope. (*Bausch and Lomb Optical Co.*)

Anyone who has not used the smaller instrument will be greatly surprised at what may be done with it; many of the important contributions to descriptive astronomy having come from 2 and 3 inch objectives during the nineteenth century. It should also be remembered that the smaller instrument can frequently be used when atmospheric conditions render the larger glass useless.

Such a glass is, of course, not as powerful as the hundred-inch reflector on Mount Wilson. Not every object of which we read can be seen with it, but that is equally true of a ten-inch telescope. A 60 mm. telescope will make it possible to see objects which are typical, and it will show them clearly and well. Objects are so numerous and interesting that there is no fear of running out of material for observation. A list of the general type objects is given:

Sun spots
Lunar phenomena including mountains and craters
Planets and their satellites
Double stars
Nebulae
Star clusters

There are also four classes of objects which offer an opportunity for valuable contributions. These are:

Novae
Variables
Comets
Meteors

Even the larger observatories cannot watch the whole sky at the same time, and serious observations and reports of these four classes of objects receive attention when forwarded to the nearest observatory.

The objects in the first group are of general interest, and change sufficiently to maintain a life-time of interest.

The following specific objects may also be seen:

PLANETS

(1) The markings on the planet Jupiter
(2) The four moons of Jupiter
(3) The phases of Venus
(4) The phases of Mercury
(5) The rings of Saturn
(6) Titan, the largest satellite of Saturn

MOON

Lunar topography such as:

Copernicus
Tycho
Alpine Valley
Cleft of Hyginus
Crater of Newton

and so on endlessly. These objects change constantly as the angle of light changes, and one never tires of going back and looking at the rugged mountains and their black shadows projecting out over lifeless plains.

SUN SPOTS

These vary from day to day and are always worthy of study; being practically the only celestial objects which may be observed during school hours. The most satisfactory way of observing these is to allow the sun's image as it leaves the eyepiece to be projected upon a smooth sheet of white cardboard. The entire class may then observe the spots at the same time and there is no danger of the eye being injured.

DOUBLE STARS

These are extremely interesting, as it is always a surprise to point the instrument at what is apparently a single star and then, when looking through the telescope, to find it has resolved into several. There are many doubles which cannot be "split" with a small telescope, since the power of resolution depends on the size of the objective.

However, a good 60 mm. glass under ideal conditions should "split" a pair of sixth magnitude stars, at least as close together as 3 seconds of arc and theoretically as close as 2 seconds of arc. This is more than ample to split such famous doubles as:

Mizar in Ursae Majors, 2 and 4 magnitudes (14 seconds apart)
E1 and E2 Lyrae, "The Double Double"
Beta Orion, 1st and 8th magnitudes, 9 seconds apart (this is a hard test)

STAR CLUSTERS

These are curious gatherings or groupings of stars in clusters or galaxies. We know that their distance is tremendous, for all that we can see with the instruments is innumerable points of light, and if we use a larger telescope we still see more points of light but just that and nothing more. Many of these star clusters are beautifully grouped and appeal to the aesthetic sense more than do any other celestial objects. The twinkling points of light frequently appear to have been placed in a definite pattern upon the black velvet background of the night sky. The astronomer Messier catalogued many of these star clusters, and the initial M before a number means that Messier discovered it. Some of the more beautiful clusters are:

M 1184
M 41
M 167
M 38 (This cluster is in Aurigae)
N 37 (Also in Aurigae)
H VI 33 and 34—The cluster in the sword handle of Perseus
The Pleiades

NEBULAE

To gaze out across the millions of miles of trackless space and observe for the first time a far-flung mass of nebulous material folded and twisted like diaphanous drapery, and to realize the immensity of such a system is to obtain a new conception of man's place in the universe. The most pleasing nebulae to observe is the great nebulae in Orion. There are also

M 57 Lyrae which is the Ring Nebulae
M 27 Vulpeculae, the Dumbbell Nebulae

It should be remembered that the light from nebulae is very weak, and only a photographic plate exposed for a long period of time will show all the details which are present.

In beginning observation with a small instrument, the observer must first be familiar with the constellations. There need be no attempt to visualize the mythical figures by which they are represented, but the group of stars should be recognized on sight, no matter what time of the year it may be. This is necessary because the small telescope must be pointed at the object directly without the aid of hour circles. Right ascension and declination are useless to help locate an object with a small telescope; its relation to other "sky marks" must be known.

Thus it is a good thing to begin with the naked eye observation, then view a few objects through an opera glass or binocular, and then pass on to the telescope. The student should be taught to find his way around in the sky and not merely be allowed to observe objects which he will not recognize or be able to locate a week later.

It should be evident, from these plain unexaggerated statements of what can be done with a small instrument, that a 60 mm. telescope is a valuable piece of equipment for the secondary school. In college work several small instruments can frequently be used when the atmospheric conditions are bad. Even in high schools where astronomy is not taught as a separate subject, a telescope should by all means be available for use in the general science classes. There is never any lack of student interest in such a course where observations are conducted frequently and where emphasis is placed on this phase of the work rather than merely memory work on distances and names.

QUESTIONS AND EXERCISES

1. Examine a ninth grade general science textbook and outline that content taken from the field of astronomy.
2. Examine an elementary science series of textbooks and outline the astronomical content for each grade.
3. What interesting features about planets can be seen with a small telescope?
4. What features of the moon can be seen with a small telescope that cannot be seen with the naked eye?
5. How can a small telescope be used to study sun spots?
6. Make a plan for using a small telescope in teaching a unit on astronomy to junior high school pupils.

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Science teachers interested in making small telescopes should procure a book published by the *Scientific American* called *Amateur Telescope Making.*

Chapter 21

PROJECTION MACHINES AND ACCESSORY EQUIPMENT

The value of pictorial teaching materials as aids to teaching and learning is accepted by everyone. Not only educators, but government branches, both military and civilian, and business organizations recognize their usefulness and effectiveness in an educational program.

A great impetus in the use of all kinds of projection machines came through their extensive and intensive use in World War II for rapid, effective training of men and women in both military and industrial skills.

It is helpful in learning to use projectors if one understands how they are constructed. Most picture-projecting devices whether they be slide, film, reflector, or motion picture machine consist of four main parts: (1) lamp-house, (2) picture carrier, (3) objective lens, and (4) screen. (See figure 49.)

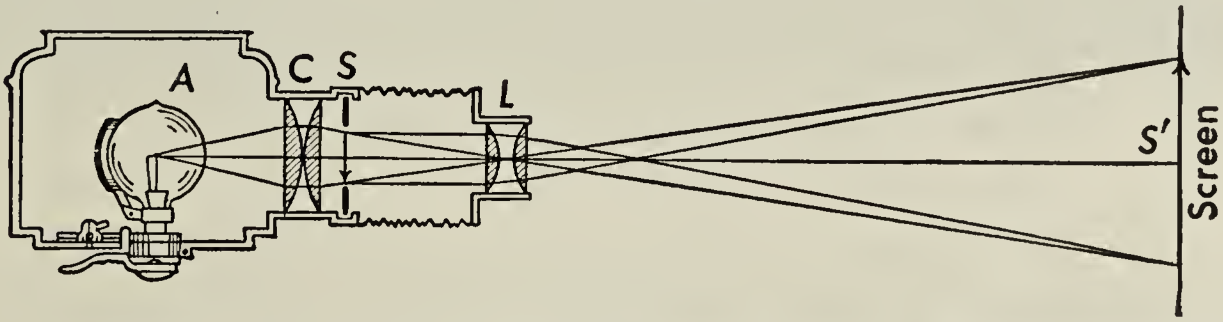

Fig. 49 The construction of a projector. A, incandescent lamp; C, condenser; S, picture carrier; L, objective lens; S′, screen. (From Black, *Introduction to College Physics. Copyright 1948 by the Macmillan Company, New York.*)

The first three parts are built as a unit. A moment's inspection will suffice to see that they are intact. The screen may be any smooth, white opaque surface. Various kinds of screens are described on page 422.

The Stereopticon or Slide Lantern

The slide lantern is a device used to project pictures from a glass slide to a wall or screen. The modern "American-made" slide consists of a piece of glass, 4 inches by 3¼ inches, upon which there is a plain or colored photograph or drawing. "European-made" slides are commonly 3¼ inches by 3¼ inches and they do not fit the "American-made" carriers.

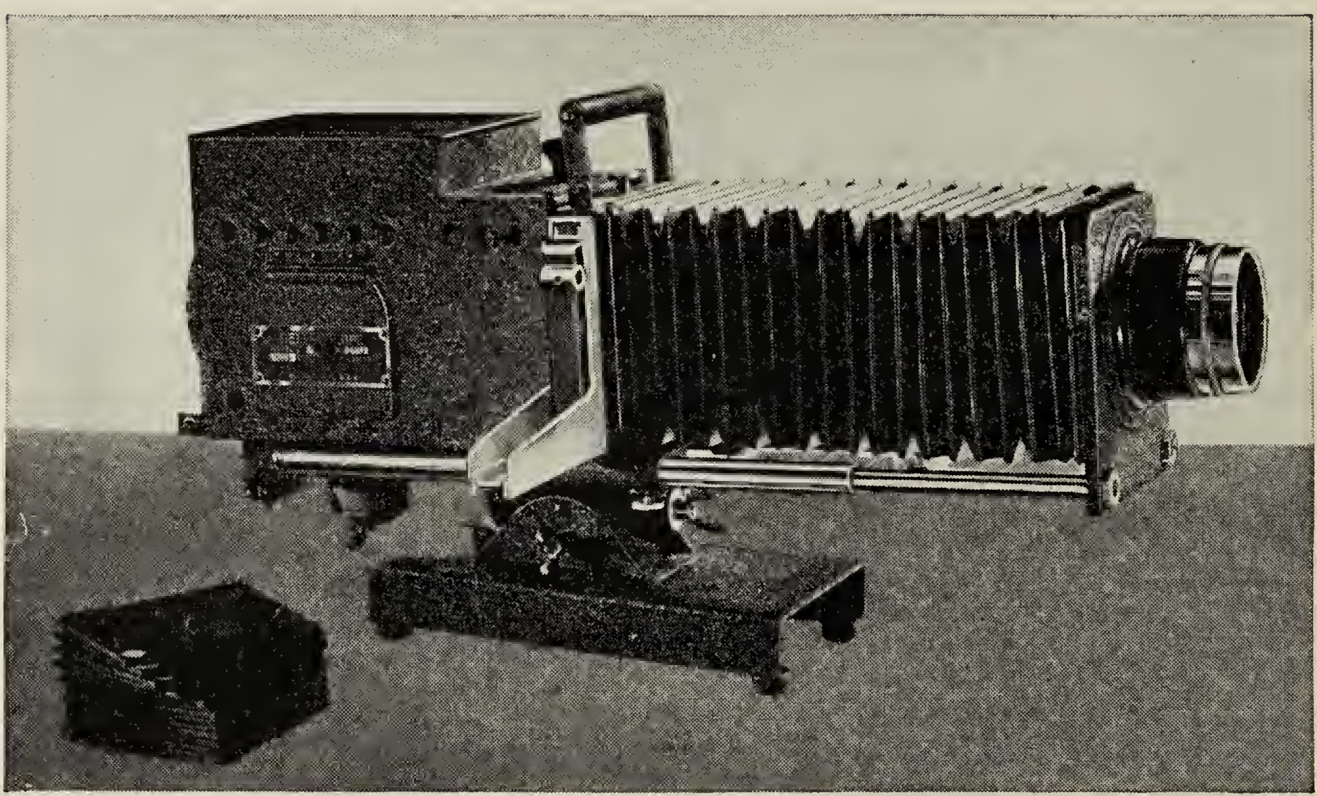

Fig. 50 A glass-slide projector. (*American Optical Co., Scientific Instrument Division.*)

The optical parts of most projectors are essentially the same. The lamp-house contains three parts. At the back of the lamp-house there is a *reflector* (a concave mirror) which reflects forward the light rays which would otherwise be lost. In front of the reflector there is an *incandescent lamp* which is the source of illumination. Ahead of the lamp, in the front part of the lamp-house, there is a *condenser* which is usually composed of two or more convex lenses. The purpose of the condenser is to concentrate the light rays on the slide which rests in the picture carrier. At the extreme front end of the projector is the *objective lens* which throws a clear image of the projected picture on the screen. The objective lens must be moved backward or forward to adjust to the distance the projector is from the screen. The objective lens is therefore mounted on a sliding rack. On some projectors the space between the objective lens and the picture carrier is occupied by a leather bellows.

How to set up the slide lantern.

(1) First ascertain the characteristics of current you have in your school. Electricity is supplied in two forms: alternating current (AC) and direct current (DC). Current is also supplied at various voltages. Make sure that your machine will operate with the current available. Most city systems supply alternating current at 110 volts (110 V.) whereas the small individual plants for farm, home, or school use frequently supply direct current at 32 volts.

An incandescent bulb will operate equally well on either direct or alternating current. It must be used only with the proper voltage. The voltage for which the bulb is adapted is marked on the bulb.

An arc lamp operates best upon direct current, though arc lights are constructed for operation on alternating current. A D-C arc lamp will not operate well with A-C current, or vice versa. The necessary facts are usually stamped upon a metal label attached to the lamp or its connected parts. The arc lamp is not now commonly used.

(2) Set the lantern on a firm table or other support, directed, as near as you can estimate, toward your screen.

(3) Connect the plug at the end of the cable leading from the lamphouse, to the outlet or socket in the room.

(4) Turn on the current and the lamp should light. Now adjust the position of your table and lantern until you get the brightest possible light falling within the margin of your screen. The size of the picture can be controlled by moving the lantern toward or awa from the screen.

(5) Darken the room as much as possible by drawing the shades. Black curtains are desirable but not necessary. If translux or other daylight screen is used, it is not necessary to darken the room. However, in this case there must be no source of light other than the lantern in the *back* of the screen.

(6) Select the slide and place it in the carrier. In order to make sure that the slides will appear on the screen right side up and with any printing correctly shown, proceed as follows: Face the screen (if using opaque screen) and hold the slide in position so that the picture appears as desired on the screen. Then rotate the slide to the left or right by 180 degrees so that is is inverted, and drop it in the carrier. *Most slides are provided with a "thumb mark"*

so placed that if the slide is turned with the mark in the upper right-hand corner when the operator faces the screen, the slide will be in proper position to drop in its carrier.

The picture will probably be out of focus. Try to focus by turning the thumbscrew on the lens mounting, or by rotating the mounting if no screw is present. If the range of adjustment is not sufficient to secure sharp focus, set the adjustment at about the middle of its range and examine to see whether there is not some provision for changing the length of the bellows (if present) or otherwise moving the whole lens assembly farther from or closer to the slide carrier. If so, make an approximate adjustment for focusing. If not, move the entire lantern, closer to or farther from the screen until approximate focus is secured. Then complete the focusing for sharp detail by means of regular adjustment. Once carefully set, the focus needs no further attention during the lecture.

(7) If using a daylight screen, the operator may use the same directions for orienting the slide, but he must stand with his *back* toward the screen. Focusing may offer some difficulty due to the dimness of the image, as seen from the operator's side. A piece of white opaque paper held against the screen is of assistance.

Types of slides. In general there are four different types of glass slides.

Photographic slides. A photographic slide is one made by transferring an image from a negative to a sensitized glass plate. The majority of slides sold by commercial firms are of this type.

If a teacher has the time and patience he can soon learn to make photographic slides. The techniques to be mastered and the apparatus and chemicals required are about the same as those required in amateur photography. An excellent little monograph giving detailed information regarding the making and coloring of lantern slides may be obtained from the Eastman Kodak Co., at Rochester, New York.

Etched glass slides. An etched glass slide is a piece of glass (4 in. by 3¼ in.) that has one side roughened by use of an acid or emery. The roughened side provides a surface upon which a diagram or drawing may be made with colored pencils, crayons, or ink.

Etched glass slides have several advantages. First, the diagram or outlines made upon them may be removed with soap and water thus permitting the slides to be used over again. Second, the slides are easy to use. If the picture is the proper size, one can lay the etched glass slide over the picture and trace in detail the outlines of the picture.

Dent[1] offers the following helpful suggestions for making etched glass slides:

"(1) If the picture to be reproduced is a free-hand drawing, it is advisable to draw it first on a piece of paper, 3¼ × 4 inches in size. If a picture is to be reproduced and is less than this size, it will not be necessary to make a sketch of it. If the picture is larger than the slide size, it is usually possible to select the important part of the picture and use it. The details of the picture should be kept within a space approximately 2¼ × 3 inches.

"(2) Lay the piece of etched glass on the drawing or picture and trace the details in outline with an ordinary medium or hard lead pencil. Mistakes in pencil may be removed with art gum.

"(3) Color the pictures with the lantern slide pencils.

"(4) If it seems desirable to preserve the picture for future use, place a piece of plain cover glass over the colored drawing and bind the edges with lantern slide binding tape. A piece of tape fifteen inches long is required to bind the glass all the way around. Wet the tape. Place it on a flat surface with the sticky side up. Hold the two glasses tightly together and place on edge in the middle of one end of the tape. Turn the glasses along the tape, being sure that the edges are being kept in the middle of the tape which will stick to the glasses. Then press the edges of the tape over the edges of the glasses and they will be bound securely.

"If the slide is not to be used over again, it will not be necessary to use the cover glass or binding tape. Furthermore, the pictures may be removed by using a little Dutch Cleanser or similar washing powder with water, or by using a lead pencil eraser on the dry glass. A small brush will be helpful if the slide is washed."

Plain pen and ink slides. This type of slide may be made very quickly and cheaply by anyone. Ordinary, plain lantern slide cover glass may be used. The following are directions for making pen and ink slides:

Clean the glass slides by rinsing them in soap and water. Then rub them dry with a soft cloth.

Coat the slides with a thin coating of clean shellac or gelatin solution. Lantern slide kits, such as the Cambosco Quickway Lantern Slide Kit, provide a box of special slide coating material with directions how to use it. Stand the slide on edge until the coating is dry and hard.

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[1] Dent, E. C., *The Audio-Visual Handbook,* The Society for Visual Education, Inc.

Draw the diagram or picture. Place the prepared slide, coated side up, over the illustration selected. The subjects may be of the science teacher's own choice. Textbooks and magazines offer a wealth of illustrative materials such as pictures, charts, graphs, and diagrams.

If desired the slide may be colored. This is done with water colors. Pigment sheets, a palette box, and several water color brushes are the materials needed. If mistakes are made while drawing or coloring the slide simply wash the slide, recoat it, and begin again. The slide may be used over and over again.

When a teacher has made a slide which he wishes to keep permanently he should finish it in the following way: Frame the picture or diagram with a cut-out mat. Over the mat place a clean, uncoated lantern slide glass cover. Hold the two plates together evenly and place them in the center of gummed binding strip. Bind the edges with the binding tape.

Cellophane slides. The cellophane slide consists of a small sheet of cellophane, 4 by 3¼ inches, bound between two pieces of plain lantern slide cover glass with binding tape.

A cellophane lantern slide is made in the following way: A piece of cellophane, 4 by 3¼ inches, is covered with a sheet of carbon paper and then typed through the carbon paper. The typing should be kept within space about 2¼ inches by 3 inches in size. The typed cellophane is then removed from the typewriter and carbon paper. It is then placed between two lantern slide cover glasses, and bound with binding tape.

The cellophane slide may be a useful tool for the busy science teacher. Outlines, assignments, and other matter usually written on the blackboard may be prepared on cellophane slides and retained for repeated use.

Instead of using cellophane between glass squares there are several other possibilities. Positive film may be placed between two plain glass slides for projection. If desired the film may be colored by hand with a Kodak water coloring set. Silhouettes and cut-outs may also be used between two glass slides. This can even be done by pupils in the lower grades.

The Overhead or Lecture Table Projector

This projector is designed for the teacher who wishes to stay at his desk, face his pupils, and operate his own machine. The machine is a modified lantern slide projector. It projects the regulation glass slide (3¼ by 4 inches).

This projector has several advantages over the ordinary lantern slide projector:

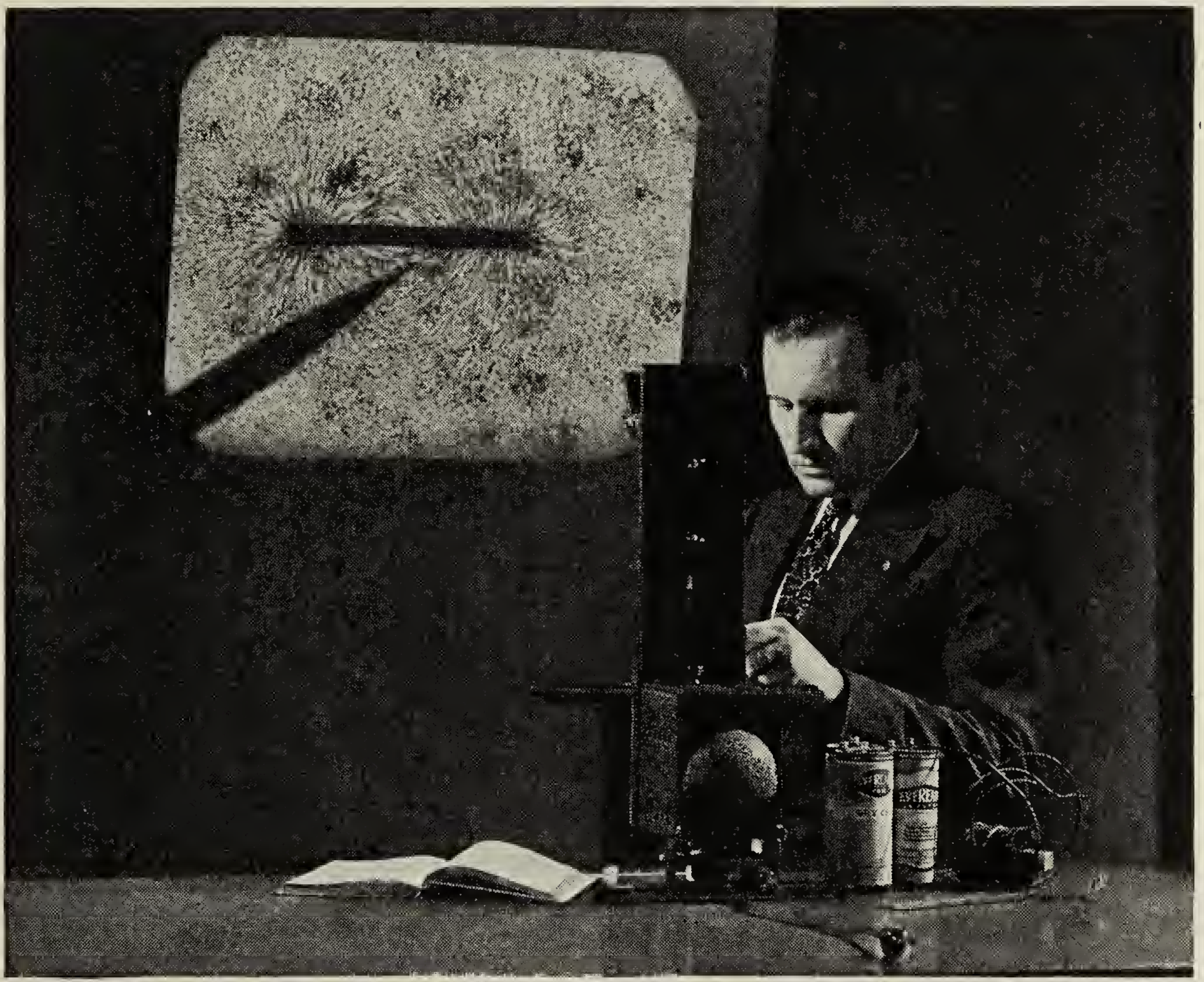

Fig. 51 An overhead projector. (*American Optical Co., Scientific Instrument Division.*)

(1) The teacher may face his pupils and at the same time operate the projector.
(2) Changing slides is extremely simple because the slides are simply laid on the top of the slide track.
(3) Slides are placed on the slide track right side up. This enables the teacher to see the slide exactly as the pupil does.

(4) Special features in the picture may be pointed out by indicating with a pencil at the slide.
(5) The screen is overhead and is visible to everyone in the room.

The Opaque Projector

In the lantern slide projector the picture is placed between the lamp and the projection lens. The light shines through the picture. If the picture is not transparent, it cannot be used.

The opaque projector (reflectoscope), on the other hand, is designed to use opaque (nontransparent) pictures such as photographs, drawings, picture postals, and cuts in books. Since the picture is opaque, the lamp is placed in front of the picture instead of behind it.

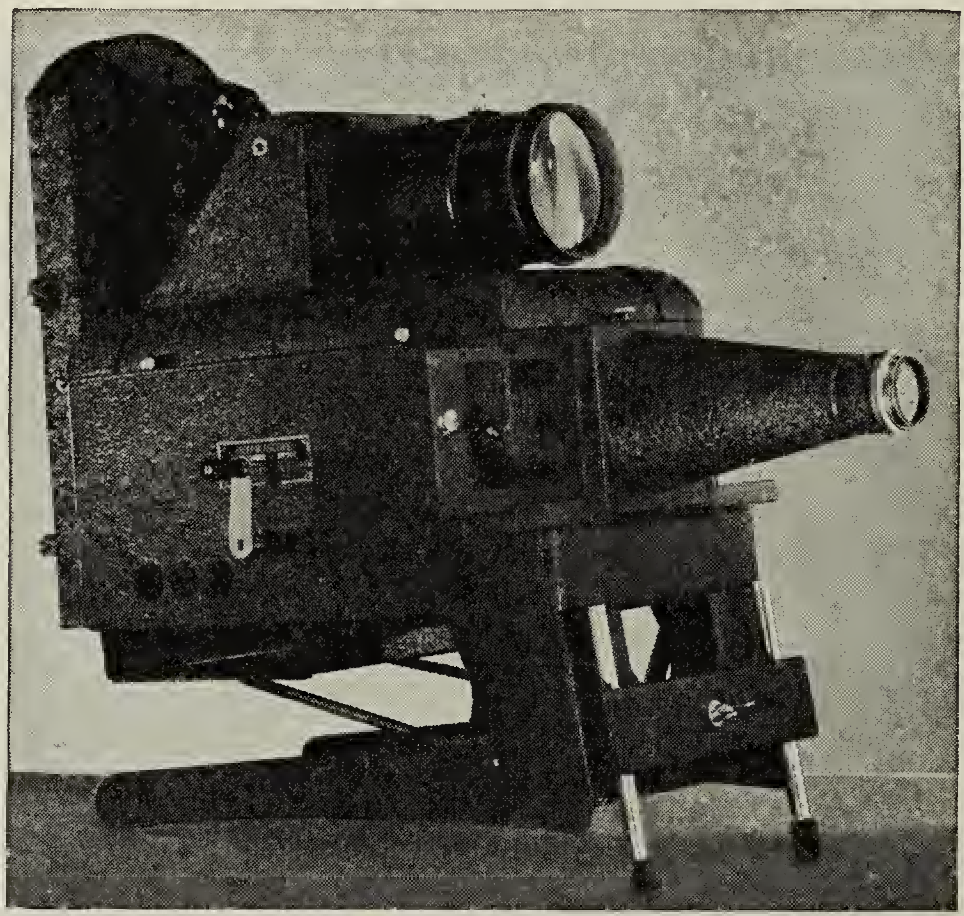

Fig. 52 A combination opaque and lantern slide projector. (*American Optical Co.*)

The place for the insertion of the picture is usually found at the bottom of the projector. Generally a spring is provided to hold the picture in place. These parts are constructed in such a manner as to allow the insertion of an entire book. This makes it possible to project illustrations from a book without removing pages. Special holders for small cards and postals are also provided. The cards may be fastened in the holders, which are slid through, somewhat like lantern slides.

Pictures may need to be inverted when inserted in an opaque projector. If the picture is reversed as to the right and left it will make little difference unless there is printing on the picture. In any case, nothing can be done about it as the reversal, if it occurs, is a characteristic of the lantern and cannot be changed. A reflectoscope which shows print correctly on an opaque or reflecting screen will show it reversed on a translux or daylight screen, and vice versa.

Focusing is done as in lanterns previously described, but requires more attention due to the fact that the pictures may not be perfectly flat and it may be necessary to refocus slightly at each change of picture.

It is necessary to use a high candlepower lamp in a reflectoscope and considerable heat is produced. It is, therefore, not wise to leave a picture in the lantern too long. Some of the more expensive models are equipped with an electric fan which keeps them relatively cool.

Many reflectoscopes are arranged to provide for projection of both opaque objects and lantern slides. The change from one type to the other is made by single movement of a lever. If you are using a combined lantern, see that the lever is set for the sort of projection you desire to use.

Schools that can afford but one type of projector should purchase the combination slide and opaque projection. Materials for use in it may be collected from many sources such as magazines, books, post cards, catalogues, and newspapers.

The Film Slide and Film Slide Projector

The film slide consists of a series of still pictures printed on a strip of noninflammable motion picture film or safety film. Still films have several advantages over glass lantern slides in that they are less expensive per picture, less bulky, and are not very easily broken. One strip of film usually contains from twenty to a hundred separate pictures. Various commercial companies have introduced film slides under different names such as film slides, filmstrips, still films, and picturols.

Film slides have one disadvantage in that the pictures on the film are in a fixed sequence. It is possible of course, to show the pictures in an irregular order by reversing the scenes as one may choose but this cannot be done very conveniently. Glass slides, however, may be placed in whatever order is desired before projection begins.

The film slide consists of a strip of cellulose acetate film 35 mm. wide and varying in length from two to five feet. The pictures begin after a short length of blank leader. The pictures are related to one topic and are organized in a definite order.

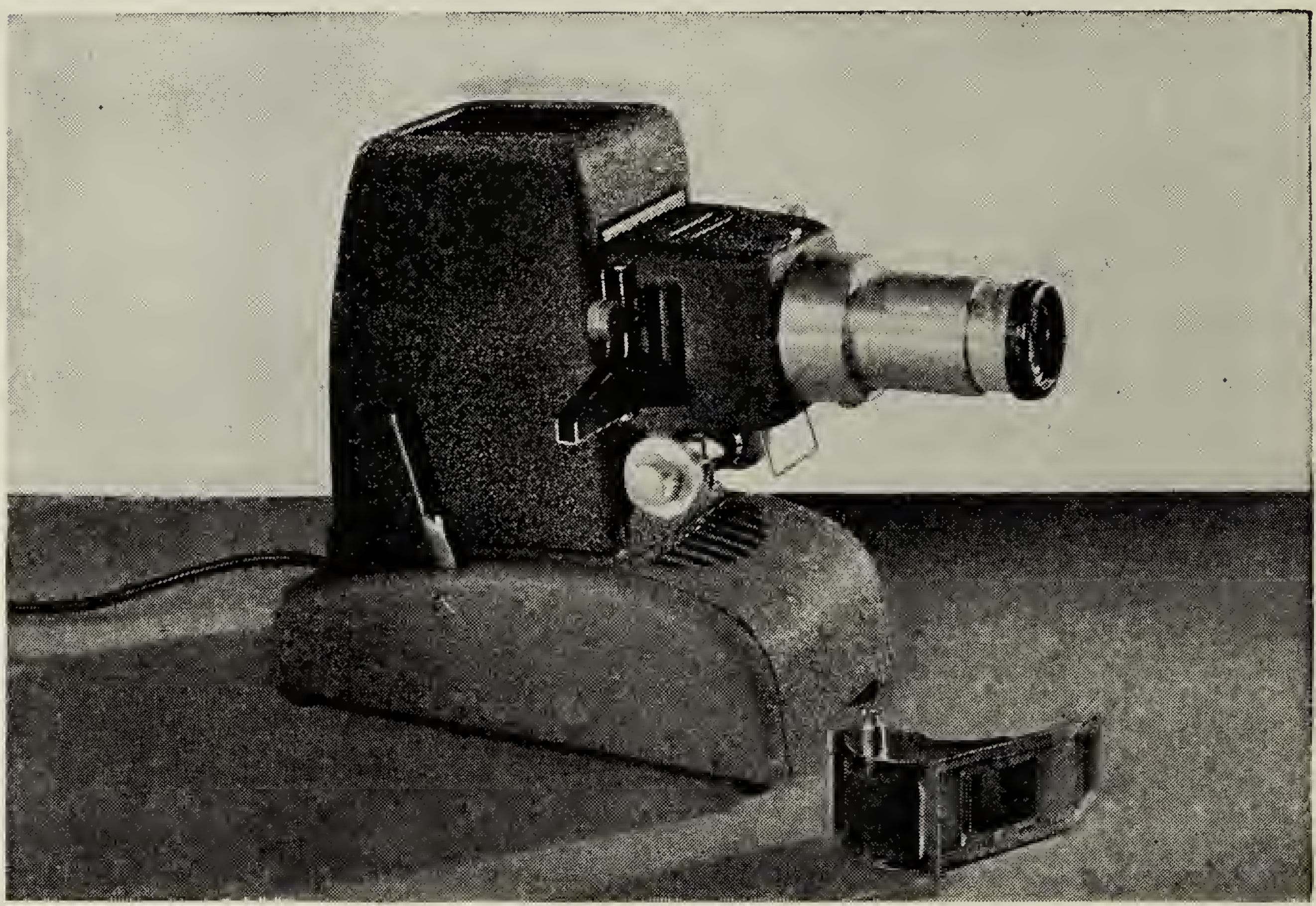

Fig. 53 A film slide projector. (*American Optical Co.*)

Still films are projected on machines with sprockets similar to those used in motion picture projectors. The size of each frame in the single-frame size is about one inch across and three-fourths inch high. The single-frame film is run through the projector vertically. On some still films the frames run horizontally instead of vertically in what is called the double-frame process. Single-frame films may be projected on any still film projector but double-frame strips can be used only in projectors designed for them. Projectors are now being made that project both single- and double-frame films as well as 2 by 2 inch slides. Since these projectors serve three different purposes they are sometimes spoken of as tri-purpose projectors (see Figure 54).

Schools which have a lantern slide projector (if it is the correct model) need not purchase a complete film slide projector. Bausch and Lomb Optical Company and the American Optical Company have, on the market, film slide attachments which fit certain of their opaque and slide lantern projectors.

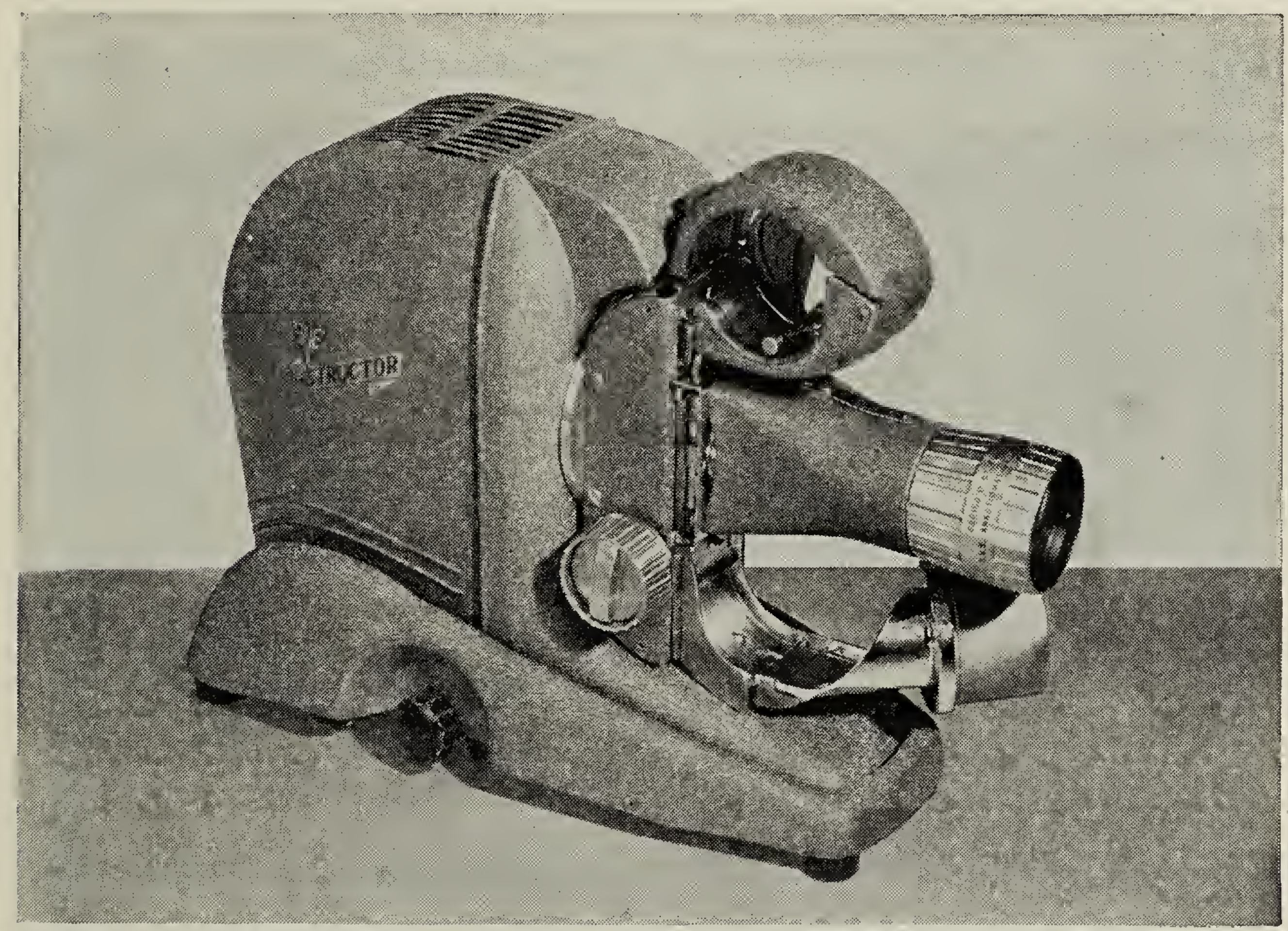

Fig. 54 A tri-purpose projector. (*Society for Visual Education, Inc.*)

The film slide projector is easy to operate. The strip of film is inserted from the side instead of from above as is done with a glass slide. The film carrier must be examined to determine how it is opened to allow insertion of the film. Several types are in use. In all carriers toothed wheels are provided which engage the perforations at the edge of the films.

It is necessary to discover at which end of the film to begin. This is usually shown by the serial number on the beginning of the series. The picture is oriented in the same way as are glass slides. The roll of film is placed above the carrier and feeds downward. Focusing is done by moving the objective lens forward or backward. The objective lens is built on a sliding rack for this purpose.

A knob or some similar device is provided for advancing the film one picture at a time. With this there is a combined device for adjusting the "framing" of the picture; that is, to make the outline of the picture correspond with the lighted area of the screen.

Motion Pictures

Motion pictures are being used increasingly by science teachers. Carefully controlled investigations show that when motion pictures are properly used they raise the achievement level of science classes. Dale[2], in his book on Audio-Visual aids, presents eleven basic values for motion pictures. He states that motion pictures can:

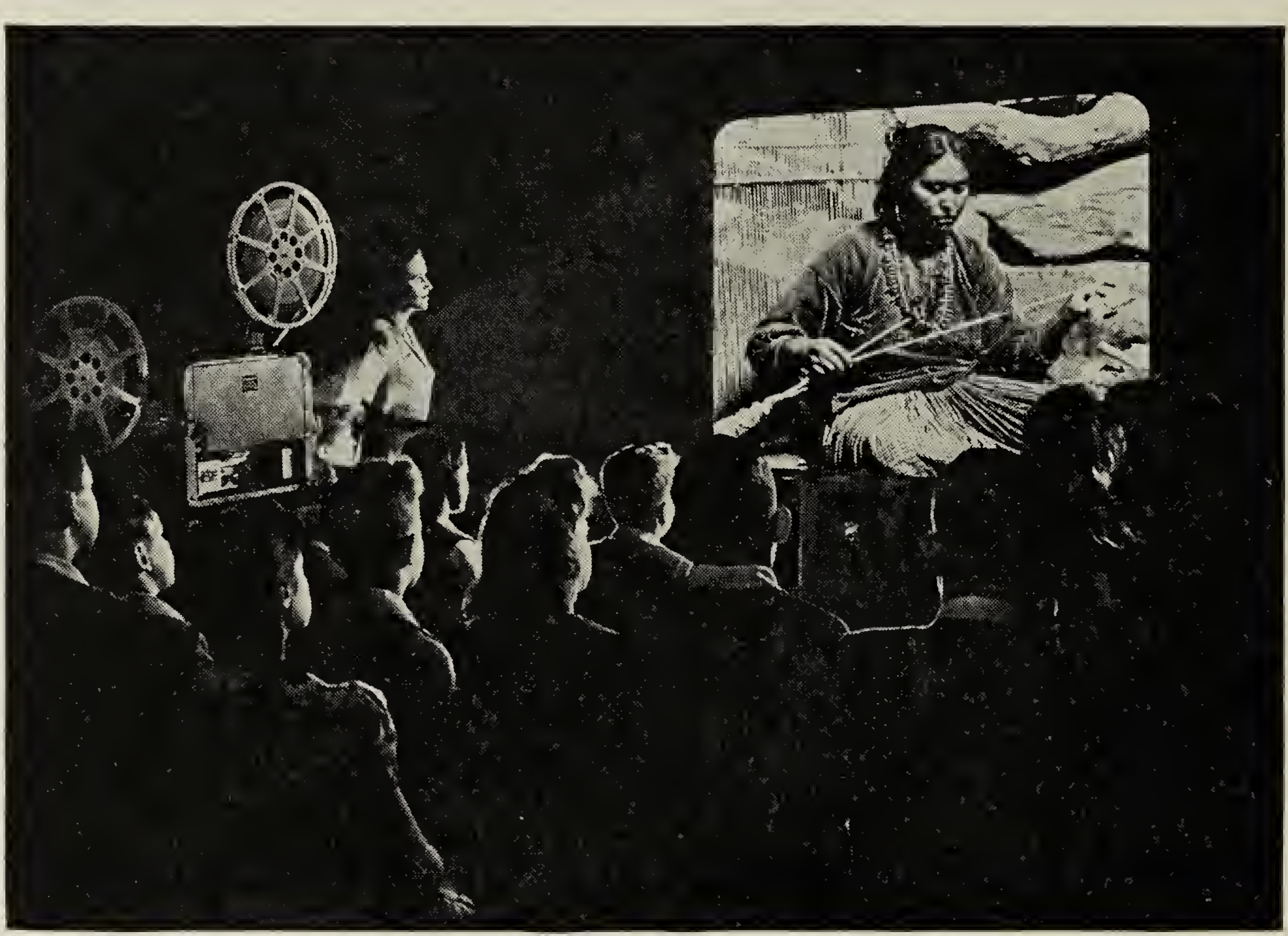

Fig. 55 A class using a 16 mm projector. (*Bell and Howell Co.*)

(1) Present certain meanings involving motion.
(2) Compel attention.
(3) Help clarify the time factor in any operation or series of events.
(4) Bring the past and the distant to the classroom.
(5) Enlarge or reduce the actual size of objects.

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[2] Dale, E., *Audio-Visual Methods in Teaching,* Dryden Press, New York, 1946, p. 191.

(6) Present a process that cannot be seen by the human eye—even by microscope and telescope.
(7) Provide an easily-reproduced record of an event.
(8) Reach a mass audience at a low average cost per person.
(9) Build a common denominator of experience.
(10) Offer a satisfying aesthetic experience.
(11) Give an understanding of relationships of things; ideas and events.

Motion pictures are tools. Their degree of effectiveness depends upon how and when a teacher uses them. Certainly a motion picture should not be used if some other teaching aid is more effective. Meredith[3] suggests the following principles as basic in the effective use of classroom films:

(1) The teacher must preview the film to be sure that it presents appropriate material.
(2) The pupils must be prepared by being informed of what they are to look for and by being made to realize that they are in a learning, rather than entertainment situation.
(3) The film must be adequately presented so that the study of it will not be handicapped by poor lighting, fuzzy sound, etc.
(4) There must be follow up procedures in which the pupils react to the film through discussing, writing, or some other form of activity.
(5) Evaluation is necessary—evaluation of pupil learning from the film, of the technique through which the film was presented and studied, and of the film itself.

Motion pictures are taken with a motion picture camera. There is no essential difference between a motion picture camera and a still camera except that in the former, pictures are taken automatically at the rate of sixteen per second on a long narrow film. The film is moved into place back of the lens by a spring and remains stationary $\frac{1}{32}$ of a second during exposure. A negative is developed from the exposed film, and a positive print is made from the negative. The positive film is run through a motion picture projector while light passes through the film to a screen, upon which images of the original objects photographed are produced.

The motion picture is an optical illusion. Motion pictures are actually a series of still pictures. Human vision persists for a little less than a sixteenth of a second after an object has disappeared from view. The illusion of motion is obtained by projecting still pictures on the screen at the rate of sixteen pictures per second. The pictures in the projector are moved forward by jerks. While the film is in motion the light is cut off by a shutter in the machine and at that instant the screen is dark. The eye, however, because of the persistence of vision, detects no period of darkness, but continues to see the picture which was visible the instant before. Before the vision of this picture dies out, another picture flashes on the screen and so on. Persistency of vision causes the individual still pictures to merge together and the human mind interprets them as motion.

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[3] Meredith, D., "Some Suggested Uses for Classroom Films," *The School Review,* LV:587–593, 1947.

The motion picture projector is a little more complicated than other types of projectors, but any teacher with a reasonable amount of mechanical aptitude can learn how to operate one and keep it in good working order. The optical parts to this projector are about the same as those found in a slide or still film projector. The motion picture projector has a lamp-house, picture carrier, and objective (projection) lens. In addition it has certain gears and gadgets which are necessary to furnish a continuous flow of film through the projector. A list of motion picture terms with definitions are supplied a little later for those science teachers who wish to become thoroughly conversant with motion picture terminology.

Kinds of film. There are two kinds of motion picture films in use in this country: the inflammable or theatrical film and the noninflammable or safety film. The inflammable type is used generally in theaters. It is made with a nitro-cellulose base which if exposed to intense heat burns very quickly. It is for this reason that states have regulations which require that this type of film be projected in fireproof projection booths.

Noninflammable or safety film is made of cellulose acetate, which, if exposed too long to the heat of a projector, blisters and shrivels. The heat of a projector is not intense enough to cause safety film to burst into a flame. Safety film is recommended for schoolroom use, because it does not need to be projected in a fireproof booth.

Motion picture film for schools comes in two widths: 35 mm film and 16 mm film. "MM" is an abbreviation for millimeters. 35 mm film is about 1⅖ inches wide. There are 16 pictures or frames to a foot of film and there are about 1,000 feet of film on a standard reel. With the projector running at average speed about fifteen minutes is required to show one reel of 35 mm silent film.

Sixteen mm film is about $\frac{3}{5}$ inches wide. It has 40 pictures or frames to a foot of film and there are 400 feet of film on a standard reel. About fifteen minutes is required to show one reel of 16 mm silent film; about ten minutes is needed for one reel of 16 mm sound film.

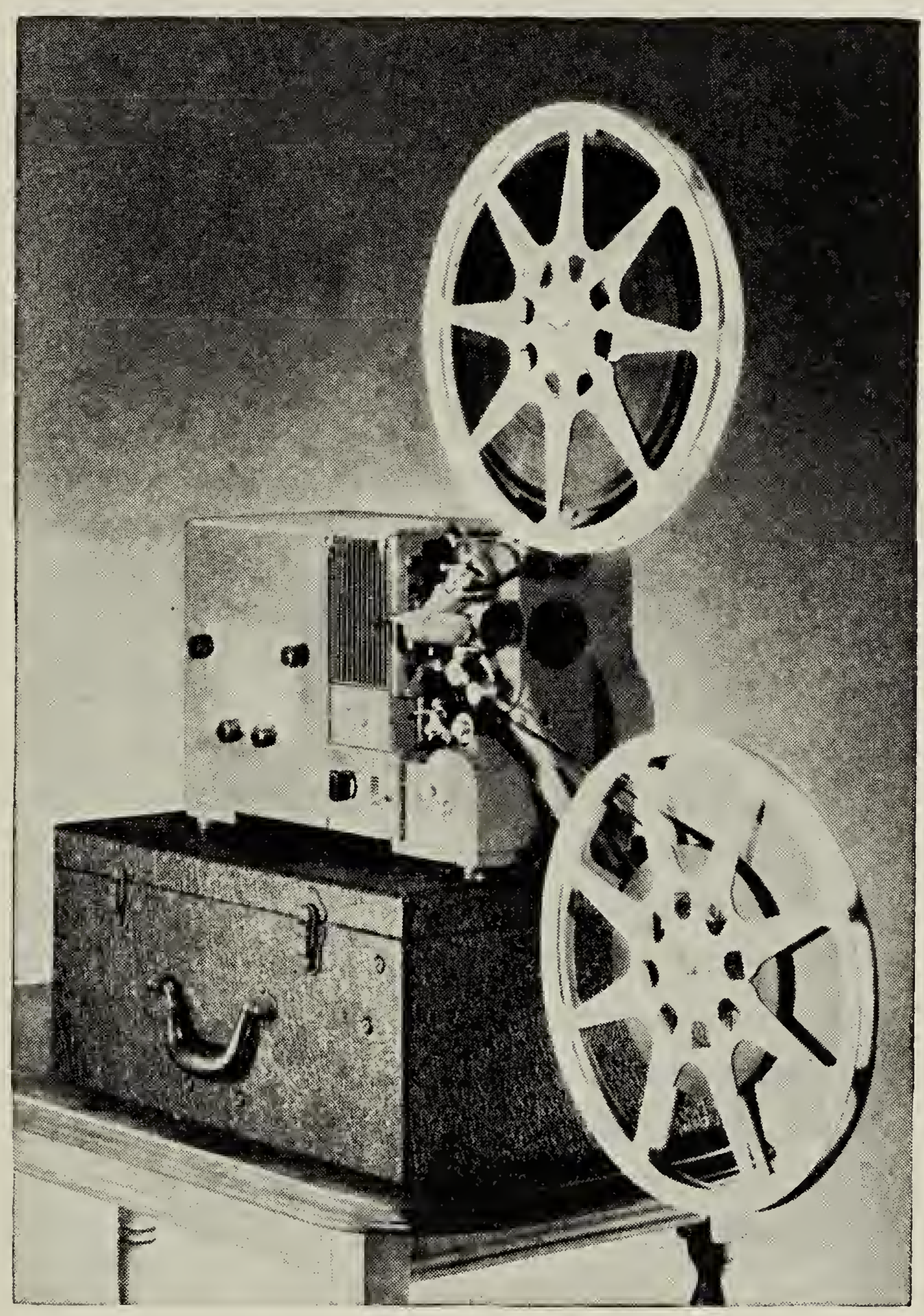


Fig. 56 A 16 mm sound-film projector.

Sixteen mm films are always printed on a cellulose acetate base. They may be used anywhere, anytime. There are no risks and no restrictions with 16 mm film. Fireproof booths are not required.

Types of projectors. Generally speaking there are two types of motion picture projectors: the standard theatrical projector and the portable projector. The large theatrical projector is used in theaters and large auditoriums. It must be installed in a fireproof booth in accordance with state regulations.

There are two different kinds of portable projectors used in schools: (1) the 35 mm film projector and (2) the 16 mm film projector. Sixteen mm film projectors are recommended for classroom use. They are smaller in size, weigh less, and they are easier to carry and operate than 35 mm film projectors. The 16 mm film projector is the ideal projector for schoolroom projection. If a school employs a 35 mm projector in the classroom, care should always be exercised to see that only safety film is used.

Sound pictures. Within recent years the educational talking pictures have been developed and they give much promise of being a valuable aid in the teaching of science and other school subjects. The manipulation of sound projection equipment is a little more complicated than the silent movie projector. However, a teacher who has already learned how to use a silent movie projector can soon learn to operate the sound picture projector by following carefully the instructions provided with the projector.

The addition of sound to the silent movie has increased the range of usefulness of the motion picture projector. It provides an opportunity to bring into the classrooms nearly life-like reproductions of many objects and processes that exist or take place outside the schoolroom building. By means of sound pictures it is possible also to bring into the classroom demonstration lectures by eminent authorities in science and science education who would otherwise not be accessible.

LIST OF MOTION PICTURE TERMS

Acetate film. Noninflammable or safety film. Where no suitable fireproof enclosure for the projector is available, only safety film may be used.

Condenser lens. A system of two plano-convex lenses placed between the film and the source of light to collect the rays of light and focus them on the film.

Exchange. A commercial agency from which motion pictures may be purchased or rented.

Film. A celluloid strip, coated on one side with a sensitive emulsion, upon which photographs are to be made; the developed negative and positive. The word is frequently used to indicate a certain motion picture or motion pictures in general; and it is sometimes used as a verb.

Film cement. A liquid medium, made of glacial acetic acid and amyl acetate, for patching and splicing motion picture films. Never use anything other than film cement for splicing film strips together.

Focus (noun). The point where rays of light passing through the lens converge.

Focus (verb). Adjustment of the lens in the projector so that the image upon the screen is sharp.

Footage. Number of feet in a film.

Frame-line. The black line that divides the top of one image from the bottom of another. When the pictures are being shown "out of frame" the line may be seen on the screen.

Frame (noun). A single photograph in a reel of film. In standard (theatrical) film each such photograph is 1 inch wide by ¾ of an inch high, and there are 16 distinct photographs to the foot. In normal projections 1 foot of film is thrown upon the screen each second. The rapid succession of images deceives the eye sufficiently to give the impression of actual motion.

Frame (verb). When the images in the film are not correctly aligned with the light in the projector, for instance, when the screen shows a man's legs and feet at the top and his trunk and head at the bottom the operator moves a lever to make the images register perfectly. This operation is called framing.

Inflammable film. *See* nitrate film.

Joining. Cementing parts of a film together.

Leader. Blank film at the beginning of a reel, placed there to aid the operator in threading the projector. Such film at the end of the reel is called the trailer.

Legends, titles, subtitles, captions. The interpretative words that explain the scenes.

Loop. A very important element in projection. Loops are the slack places left in the film at certain points when it is threaded through the projector, so that it can be jerked down one frame at a time without being damaged.

Negative. Film exposed in a camera and then developed by chemical reaction so that the image is brought out and made permanent. The blacks and whites of the image, however, are reversed. When a positive print is made from the negative, the blacks and whites are placed in their true relation.

Nitrate film. Inflammable film. Film that burns very rapidly when ignited.

Perforations. The holes on both edges of the film. In standard film there are 4 perforations on both sides of each frame.

Positive. Film exposed to the action of light behind a negative and then developed. A positive is the opposite of the negative. It is the image of the positive that is thrown on the screen by the projector.

Print. A positive film. As many prints as are desired can be made from a negative.

Printing. The process of acting upon positive film by passing it through a machine in company with a negative against a source of light.

Projection or objective lens. The lens that focuses upon the screen, the rays of light from the lamp.

Projector. A machine containing a powerful source of light and a mechanism that passes the film between the light and the lens which magnifies the image film and throws it upon the screen. Each frame, or image, in the film is halted for a fraction of a second in the path of the light and then moved on. This is called intermittent movement.

Reel. The spool upon which the film is wound for use in the projecting machine. A reel of 35 mm. film contains approximately 1,000 feet. A reel of 16 mm. contains about 400 feet. The projection of one full reel, requires, on the average, 15 minutes.

Release. To place a motion picture in distribution, the act of doing so, or the motion picture concerned.

Rewinder. The mechanism that reverses the winding of a film so that the beginning of the film will lie on the outside of the reel, dull side out, ready for projection.

Safety film. *See* Acetate film.

Safety shutter. In a projector the little door that falls between the lamp and the film when the machine stops or runs so slowly that there is danger of igniting the film.

Screen. The surface upon which the image is thrown.

Shutter. In projectors, the 2-wing or 3-wing revolving device that intercepts the light as the film is jerked down one frame at a time, and, by multiplying the flickers on the screen, tends to make them less apparent.

Splice. To join, by cementing, one piece of film with another.

Split reel. A reel containing two or more subjects under different titles.

Sprocket. The revolving toothed wheel which moves the film through the projector by engaging the perforations.

Take-up. In a projector, the mechanism used in winding the film after it passes the projecting aperture.

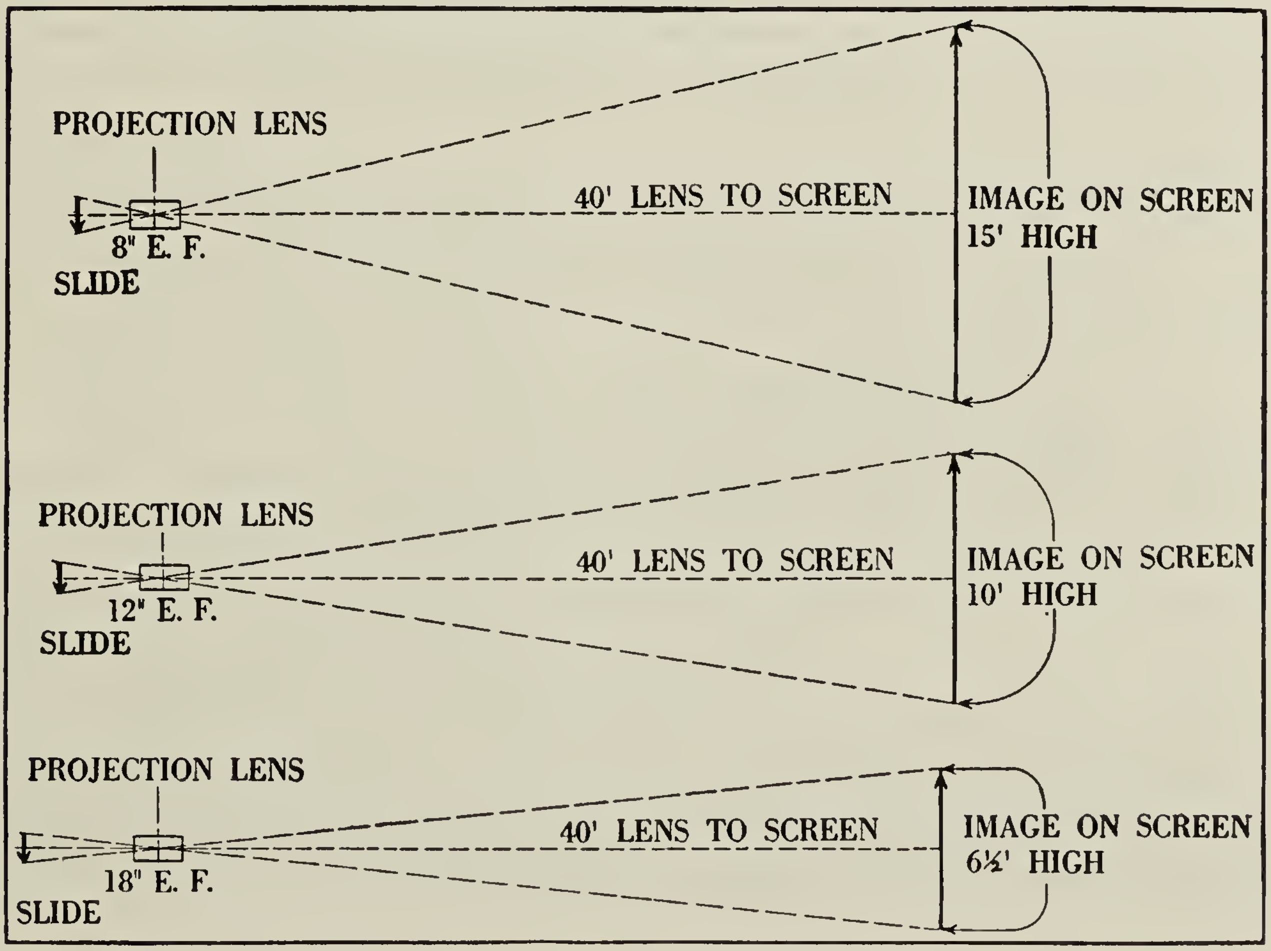
Thread. To pass positive film through the projector so that when the machine is operated the images will be thrown upon the screen, so that the film will wind properly from one reel to another.

Throw. Distance from the projector to the screen.

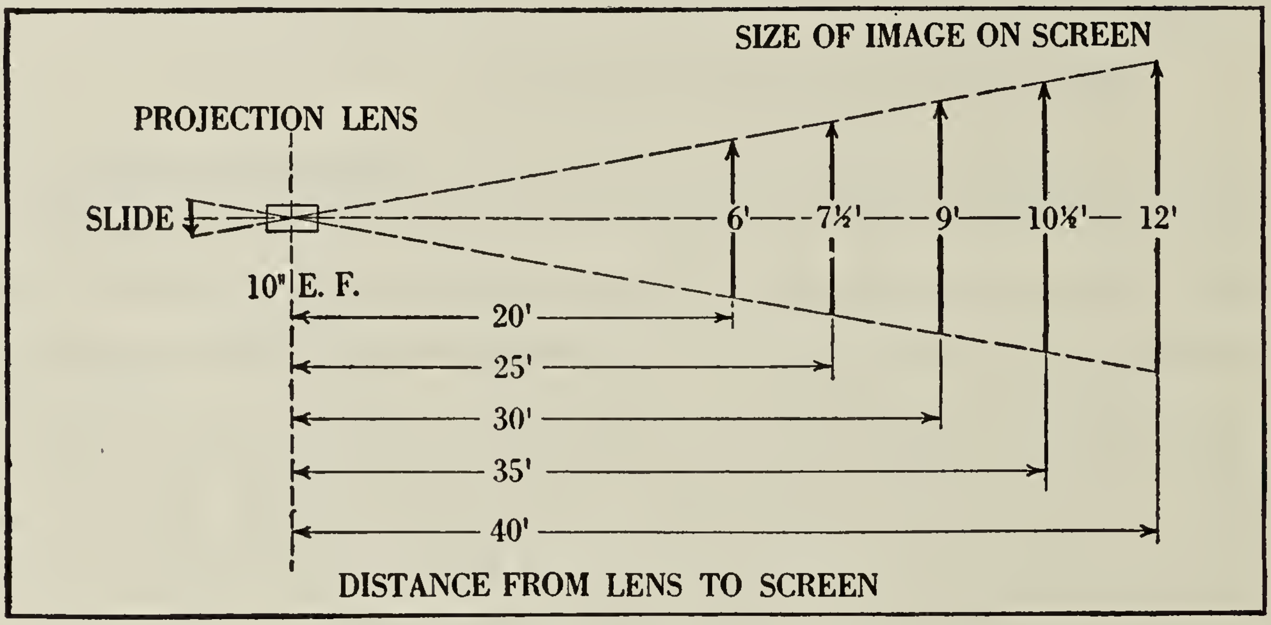
Purchasing Projection Machines

In purchasing a projection machine for the projection of opaque objects, still film, or lantern slides, it is important that the teacher select a machine with the *correct focal length of lens* to meet the conditions under which the machine will be used. The equivalent focal length (E. F.) of a lens or combination of lenses is the distance from the lens to a point at which all the rays coming from a distant object would form a sharp image. The focal length therefore is directly proportional to the distance from lens to screen and inversely proportional to the size to the image on the screen.

The three diagrams below illustrate how the size of the image on the screen is inversely proportional to the focal length of the projection lens, when the distance between the lens and the screen remains constant.


PROJECTION LENS
8" E. F.
SLIDE
40' LENS TO SCREEN
IMAGE ON SCREEN
15' HIGH
PROJECTION LENS
12" E. F.
SLIDE
40' LENS TO SCREEN
IMAGE ON SCREEN
10' HIGH
PROJECTION LENS
18" E. F.
SLIDE
40' LENS TO SCREEN
IMAGE ON SCREEN
6½' HIGH

The following diagram shows the size of the image on the screen is directly proportional to the distance the image is from a given lens.


SIZE OF IMAGE ON SCREEN
PROJECTION LENS
SLIDE
6'
7½'
9'
10½'
12'
10" E. F.
20'
25'
30'
35'
40'
DISTANCE FROM LENS TO SCREEN

It is also important to keep in mind that the intensity of illumination per unit of area, varies inversely as the square of the width of the picture. The larger the picture the less brilliant it will be.

TABLE 4

FOR LANTERN SLIDES, 2¾ BY 3 INCH MAT OPENING

Focus of Lens in Inches	Distance from Lantern to Screen												
	15 ft.	20 ft.	25 ft.	30 ft.	35 ft.	40 ft.	45 ft.	50 ft.	60 ft.	70 ft.	80 ft.	90 ft.	100 ft.
6	7½	10	12½										
8	5½	7½	9½	11¼	13	15							
10	4½	6	7½	9	10½	12	13½						
12	....	5	6¼	7½	8¾	10	11¼	12½	15				
15	....	4	5	6	7	8	9	10	12	14	16½		
18	....	....	....	5	5¾	6½	7½	8¼	10	11½	13	15	16½
20	....	....	....	4¼	5	5¾	6½	7¼	8¾	10¼	11¾	13¼	14¾
22	....	....	....	....	....	5¼	5¾	6½	8	9¼	10½	12	13¼
24	....	....	....	....	....	4¾	5¼	6	7¼	8½	9¾	11	12¼

Example—A 10 inch lens used at a distance of 40 feet from the screen will project an image measuring 12 feet on its longer side.

After the teacher or administrator has established the two determining factors, the size of image desired and the distance the projector is to be placed from the screen, he need only refer to a table similar to Table 4 to find out the focal length of lens required for his particular situation.

Screens for Use with Projection Machines

Successful projection of pictures is dependent in part upon having available a suitable reflecting or transmitting surface. With black-and-white slides, the blackboard may sometimes be used. A white or light-colored wall of the room, if suitable space is available, may function as a screen. Heavy white muslin or the back of a good spring-roller map will serve as a fairly efficient screen.

There are also various kinds of screens available which are sold under many different trade names. There are two main types of manufactured screens: (1) those which reflect the picture and (2) those which transmit the picture. The first type is called the reflecting screen and the second type is called the translucent or "daylight screen." With a reflecting screen the projector is placed in front of the screen at the back or toward the back of the room. With a transslucent screen the projector is placed back of the screen at the front of the room.

In addition to the cost of a manufactured reflecting screen there are two factors to be considered when buying such a screen: (1) the direct reflective power of the screen and (2) the largest angle to which the screen will reflect pictures satisfactorily.

Aluminum-coated screen. This is a canvas screen covered with a metallic coating of powdered aluminum. It reflects well, and its angle of reflection is about 30 degrees. The aluminum-coated screen gives better results than the usual homemade screens in larger rooms where the projection distance is greater.

Beaded screens. The surface of this screen is covered with small glass beads. This type of screen gives the highest direct reflection of light of all screens. It is limited in use, however, because it has a very small angle of reflection (about 8 degrees). The beaded screen is recommended for use in situations where brilliant illumination is required and where the room is long and narrow. If the beaded screen is used in a short square room, the picture on the screen will appear distorted to those pupils who sit at the side of the room.

Mat-white screens. This type of screen usually has a white silk surface which gives satisfactory reflection at wide angles from the reflecting surface. It gives a true reproduction of color which makes it a desirable type of screen to use with colored slides.

Translucent or "Daylight" screens. The use of the term "Daylight" screen is apt to be confusing. It is well to remember that there is no screen which will give entirely satisfactory service when outside light is present to any great degree. As stated before, translucent screens are screens which transmit light from the reflector to the class. The projector is placed behind the translucent screen which usually stands on a tripod in front of the teacher's desk. To obtain the best results with this screen, it is necessary to have the room in semidarkness.

TROUBLES AND THEIR REMEDY

The teacher who uses projection machines will encounter difficulties at times. The following suggestions should prove helpful to teachers inexperienced with projection machines.

(1) Light out.
  (a) Current off. Test by turning on the room lights. If the room lights do not light up, a fuse may be burned out or the current may have been cut off temporarily by the electric company. Check the fuse in the movie projector.
  (b) Switch may be turned off. Examine.
  (c) Lamp may not be firm in its socket. Give it a turn.
  (d) Filament in lamp may be broken. If so get a new lamp of proper wattage and voltage.
  (e) The wire in the cable may be broken. Have the cable tested.
(2) Will not focus.
  (a) The lamp may be too far from the lens or too close to the lens.
  (b) If there is a dark space at the top or the bottom of the picture the lamp may be too high or too low in relation to the lens.
(3) Picture not clear.
  (a) The slide may be too dark.

(b) The room may not be dark enough. Dark curtains may be needed.
(c) Lens or condensers may be dirty.

(4) Picture the wrong size.
(a) If the picture is too large for the screen, move the lantern closer to the screen.
(b) If the picture is too small for the screen, move the lantern farther away from the screen.

SOURCES OF PROJECTORS AND ACCESSORY EQUIPMENT

The science teacher should write to the following firms for free catalogues and descriptive materials. Some State Museums lend slides to teachers within their state. Write to your State Museum for information.

Commercial Slides

Academy of Science, Chicago.
American Museum of Natural History, New York.
Bailey Art Slide Co., 21 Lake Ave., Newton Center, Mass.
Biological Supply Co., 34 Union Square, New York.
Eastman Educational Slides, Iowa City, Iowa.
General Biological Supply House, 761 East 69th Place, Chicago.
Keystone View Company, Meadville, Pa.
Lick Observatory, Mt. Hamilton, Calif.
National Association of Audubon Societies, New York.
National Geographic Society, Washington, D. C.
National Park Service, Department of Interior, Washington, D. C.
National Studio's Inc., 226 West 56th St., New York.
Victor Animatograph Co., Davenport, Iowa.
Visual Education Service, Inc., 7024 Melrose Ave., Los Angeles, Calif.
Welsh, W. M., Manufacturing Co., 1516 Orleans St., Chicago.
Williams, Brown & Earle, Inc., 918 Chestnut St., Philadelphia, Pa.

Slide-making Materials, (plain glass slides, etched glass slides, mats, cover glasses, binding tape, cellophane, colored pencils, colored inks)

Cambridge Botanical Supply Co., Cambridge, Mass.
Celluloid Corp., 290 Ferry St., Newark, N. J.
Eastman Kodak Co., Rochester, N. Y.
Keystone View Co., Meadville, Pa.
National Theatre Supply Co., 90 Gold St., New York.
Radio Mat Slide Co., Inc., 1674 Broadway, New York.
Scarborite Colors, Inc., Scarborough-on-Hudson, N. Y.
Victor Animatograph Company, Davenport, Iowa.

Slide Lantern Projectors

Bausch and Lomb Optical Co., Rochester, N. Y.
Keystone View Co., Meadville, Pa.
American Optical Co., Buffalo, N. Y.
Victor Animatograph Company, Davenport, Iowa.

The Overhead or Lecture Table Projectors

Bausch & Lomb Optical Co., Rochester, N. Y.
American Optical Co., Buffalo, N. Y.

Opaque Projectors

Bausch & Lomb Optical Co., Rochester, N. Y.
American Optical Co., Buffalo, N. Y.
Trans-Lux Daylight Picture Co., 247 Park Avenue, New York.

Film Slide Projectors and Attachments

Agfa-Ansco Corp., Binghamton, N. Y.
Bausch & Lomb Optical Co., Rochester, N. Y.
E. Leitz, Inc., 730 Fifth Ave., New York.
Society for Visual Education, 327 South La Salle St., Chicago.
American Optical Co., Buffalo, N. Y.
Victor Animatograph Co., Davenport, Iowa.

Film Slides

Bray Pictures Corp., 130 West 47th St., New York.
General Electric Co., Motion Picture Division, Schenectady, N. Y.
National Park Service, Department of Interior, Washington, D. C.
Nature Study Illustrated, San Jose College, San Jose, Calif.
Society for Visual Education, 327 South La Salle St., Chicago.
American Optical Co., Buffalo, N. Y.
United States Department of Agriculture, Washington, D. C.
University Museum Extension Lecture Bureau, 10 South 18th St., Philadelphia, Pa.
Visual Instruction Service; University Museum, University of Pennsylvania, Philadelphia, Pa.
Visual Text Sales Company, Los Angeles, Calif.

Micro-Projectors and Euscopes

Bausch and Lomb Optical Co., Rochester, N. Y.
American Optical Co., Buffalo, N. Y.

Motion Picture Projectors

Ampro Corporation, 2839 North Western Ave., Chicago.
Bell & Howell Co., 1801 Larchmont Ave., Chicago.
Eastman Kodak Co., Rochester, N. Y.
Herman A. De Vry, Inc., 1111 Center Street, Chicago.

International Projector Corp., 90 Gold Street, New York.
Victor Animatograph Corp., Davenport, Iowa.

QUESTIONS AND EXERCISES

1. What are the four main parts of a projector?
2. What are the different types of glass slides available for science teachers?
3. What advantages does the overhead projector have over the ordinary lantern-slide projector?
4. How does an opaque projector differ from a lantern-slide projector?
5. What are the advantages and disadvantages of film slides as compared to glass slides?
6. What are the basic principles a teacher should follow in order to make motion pictures effective in the classroom?
7. What are the advantages of a 16 mm motion picture projector over a 35 mm projector for classroom use?
8. If you had money enough to buy but one projector for your school which one would you select? Give your reasons.
9. If you were buying a projector how would you determine the correct focal length lens to use in your classroom?

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Chapter 22

SOUND SYSTEMS

Some of the more recent teaching aids employ a sound system of one kind or another. Since some of these sound systems are very complex the teacher should first become acquainted with the components of a simple sound system. An understanding of the important features of these components is essential, especially in the selection of a sound system.

In the first part of this chapter, the teacher will find a description of the components of a simple sound system. Later, various combinations of these components will be described for such teaching aids as recorders, record players, public address systems, radio, television and audio-visual projection apparatus. If detailed technical information is neeeded, the teacher should consult the references or write to the companies direct.

Selecting the Proper Microphone

The microphone is the most important component of a sound system. Prime consideration should be given to its selection on the basis of the following:

(1) *Indoor and Outdoor Uses*

"Pressure" microphones are excellent for outdoor use. The dynamic type is the most popular. They withstand the effects of high and low temperatures, mechanical vibrations, wind and humidity. "Velocity" or "Ribbon" microphones are very sensitive and are used mostly indoors. If used outdoors, winds may activate the "ribbon" and produce noises in the system unless the winds are minimized. "Crystal" microphones are severely affected by high temperatures and high humidity. In outdoor use, where these high conditions do not prevail, they are excellent.

(2) *Directional Characteristics*

"Non-directional" microphones receive sound from all directions and afford good coverage where the audience completely surrounds them. "Bi-directional" microphones receive front and back sounds only. These are used best for conversation between persons located on each side of the microphone, as in debates or quizzes. "Uni-directional" microphones receive sound from one direction and are best in stage or platform presentations since they exclude background noise.

(3) *Protection against "Squeals and Howls"*

When the sound coming from the loudspeaker is reflected back into the microphone, echoes result. These echoes arise from carpetless floors, bare walls or ceilings, and may be eliminated by the following:

(a) Selecting the proper location of the loudspeakers with respect to the microphone. In general, loudspeakers should be placed over and behind the microphone.
(b) Placing heavy draperies over windows and walls with heavy floor carpets.
(c) Using a uni-directional, lower sensitivity microphone.
(d) Turning "dead" sides of microphone to face the reflected sounds.

(4) *Distance between Microphone and Sound Source*

"Pressure" microphones operate well in areas of high noise level or where close talking or paging are used.

"Velocity" microphones should be operated some distance from the source of sound because of high sensitivity. The "ribbon" type is the best to use under certain conditions, as when speakers or actors move away from the microphone.

(5) *Distance between Microphone and Amplifier*

"High impedance" microphones and amplifiers should not be located more than fifty feet apart unless a signal loss can be tolerated. If a distance of more than fifty feet is required, low impedance equipment may be needed and this is more expensive than the high impedance set-up.

(6) *Some Features of Microphones*

A tilting head is always an advantage in a microphone since it can invariably be made to face the sound source.

Long cable connector plugs make possible disconnection of microphones when moving from one location to another.

Portability is a great advantage in group interviews where the microphone is hand-held, or among crowds where the hand-held microphone can roam with the announcer. Mechanical vibration can affect the efficiency of the microphone unless a rubber shock mount between handle and microphone head is present. Compactness and flexibility are important because a small unit, flexible in operation, will not distract audience attention from the speaker.

Selecting the Right Amplifier

When considering a particular sound installation, it is just as important to select the right amplifier as it is to select the proper microphone. Some of the important considerations are:

(1) Input Channels.
These are the "trunk" lines through which the sound passes into the amplifier. Such inputs may be provided for one microphone and one phonograph. Others may be provided for two microphones, one phonograph, and one for microphone or phonograph.

(2) Control Provisions.
Most amplifiers are provided with volume controls, tone control and power switch. The flexibility of operation of these controls is of prime consideration when the number of inputs, as previously described, is limited.

(3) Overall Gain.
This is the amplifying capacity; high gain amplifiers are required when using highest quality microphones. In any case, the amplifier should supply enough gain to handle nearly all low voltage microphones, such as low output dynamic pick-ups and crystals.

(4) Output Power.
This is expressed in such ratings as 6, 15, 20, 30,—watt amplifiers. Distortion may occur at "peak" watts output so that operation alone should not be judged solely on watts of output power.

(5) Distorted Reproduction.
Hum and distortion will affect reproduction of the sound and should be considered along with the power output. Usually the amplifier is adjusted to keep the hum below the point where it is noticed by the ear.

(6) Replacement Costs.
If the amplifier is used at the proper power output rating, there may be little need for replacements such as tubes.

(7) Frequency Range.
A wide frequency range at full output of the amplifier should be available.

Selecting the Right Speaker

A knowledge of speakers and their components is very helpful in choosing the proper one for your sound system.

Like microphones, speakers and their components may have certain characteristics.

(1) Characteristics of Speakers.
  (a) Directional coverage to a limited area
  (b) Non-directional coverage but over a wide area
  (c) Indoor or outdoor use with proper protection
  (d) Low power output or high power output depending on requirements for intensity of the sound needed at the location
  (e) Speech response only, as for paging, or speech and music frequency response.

(2) General Kinds of Speakers.
  (a) Cone Mechanisms and Baffles, where the sound is radiated by a cone and baffled for more efficient sound reproduction.
  (b) Horn Mechanisms and Baffles, where higher power output and rugged construction are needed for such as outdoor directional use or indoor machine shop usage.
  (c) Matching transformers to insure that the electrical load of the speakers matches with the amplifier for best sound reproduction.

Recorders and Playbacks

Various combinations of the components of a simple sound system can be found in the selection of a recorder. This teaching aid has come to be a prominent part in each of the following:

(a) Public Speaking Classes
(b) Speech Correction Classes
(c) Dramatic Club Activities
(d) Recording Discussion Groups
(e) Recording the School Orchestra or Band
(f) Recording Guest Speakers and Forums
(g) Recording historical events from Radio and Television
(h) Studying foreign languages

Four types of sound recorders are now available: the *disc,* the *wire,* the *tape,* and the *film* recorder. A partial listing of the manufacturers of these different types is given at the end of the chapter.

The *disc* recorder uses a stylus which cuts a groove or "embosses" the sound. "Micro-Grooving" is now being used to obtain much longer recording time and greater compactness, since the grooves are many more in number and thinner on a disc the same size as the ordinary record. This process is done by means of a light-weight head and a special needle having a point-radius of about one third that of the ordinary record needle. This produces roughly three micro-grooves to one ordinary groove. A typical Disc Recorder is shown in Figure 57.

The *wire* recorder operates on the principle of magnetising a wire made of steel or alloy. The magnetising is done on small sections of the wire producing first one polarity and then the other. The length of each polarised section will depend on the frequency of the sound recorded. When these small polarized sections are drawn over a recording "head" they produce an alternating voltage at the frequency of the sound recorded. This alternating voltage is so weak that an amplifier is used to produce higher voltages which will be sufficient to activate the speaker. The alternating voltage from the amplifier is then converted to mechanical vibrations in the speaker, thus reproducing sound.

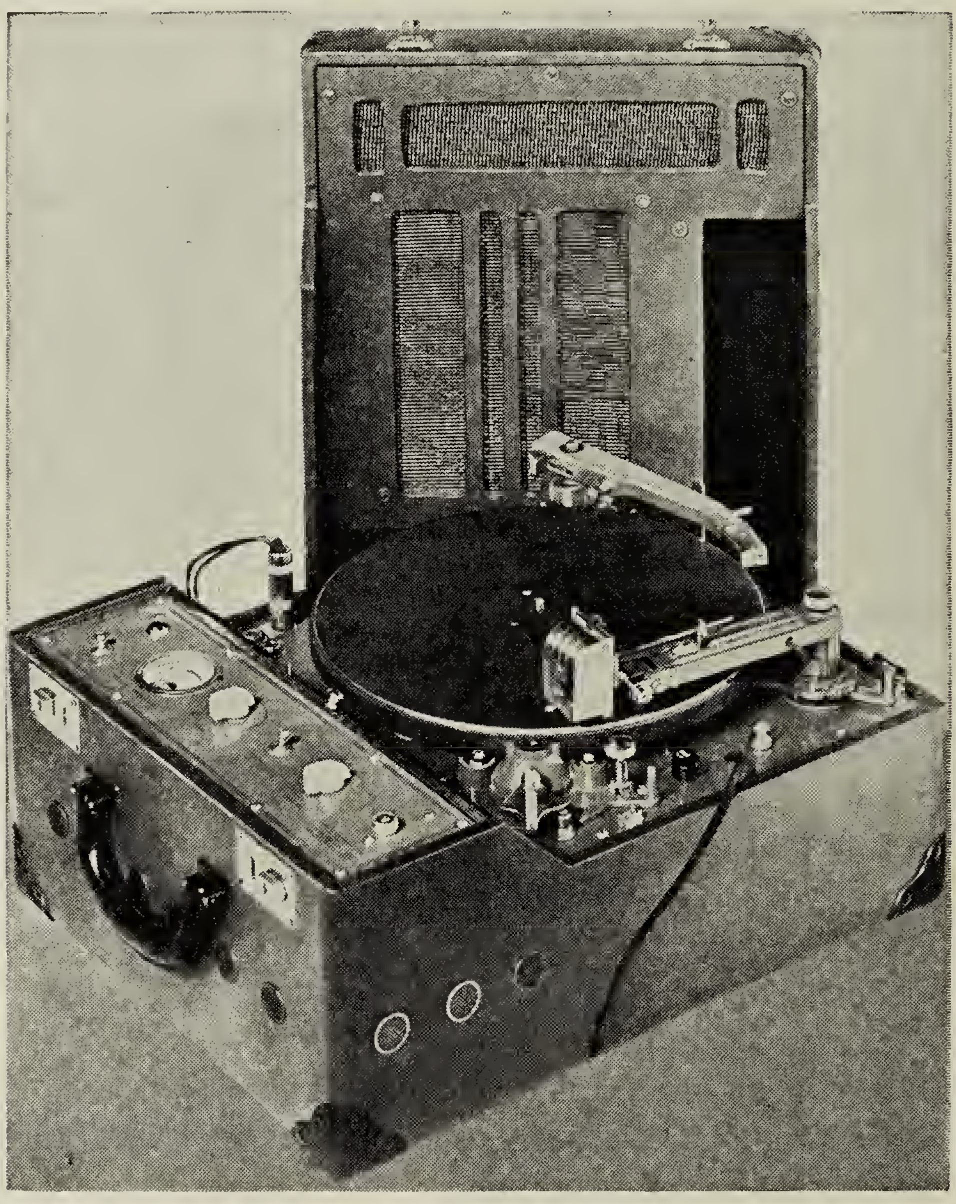

Fig. 57 A typical disc recorder. (*Presto Recording Corp.*)

The *tape* recorder operates on principles somewhat similar to that of wire recorder. The ¼ inch thin paper or plastic tape contains magnetic material, usually iron oxide, and is pulled through the recording "head" by a constant speed "capstan" but at a rate slower than for wire. Tape always presents the same face to the recording head. Tape can be cut and spliced together with cellulose tape, thus making it possible to "edit" a recording. The speed is the same at all parts of the record and the magnetic material is influenced by the recording "head," in much the same way as that described under the wire recorder. A typical tape recorder is shown in Figure 58.

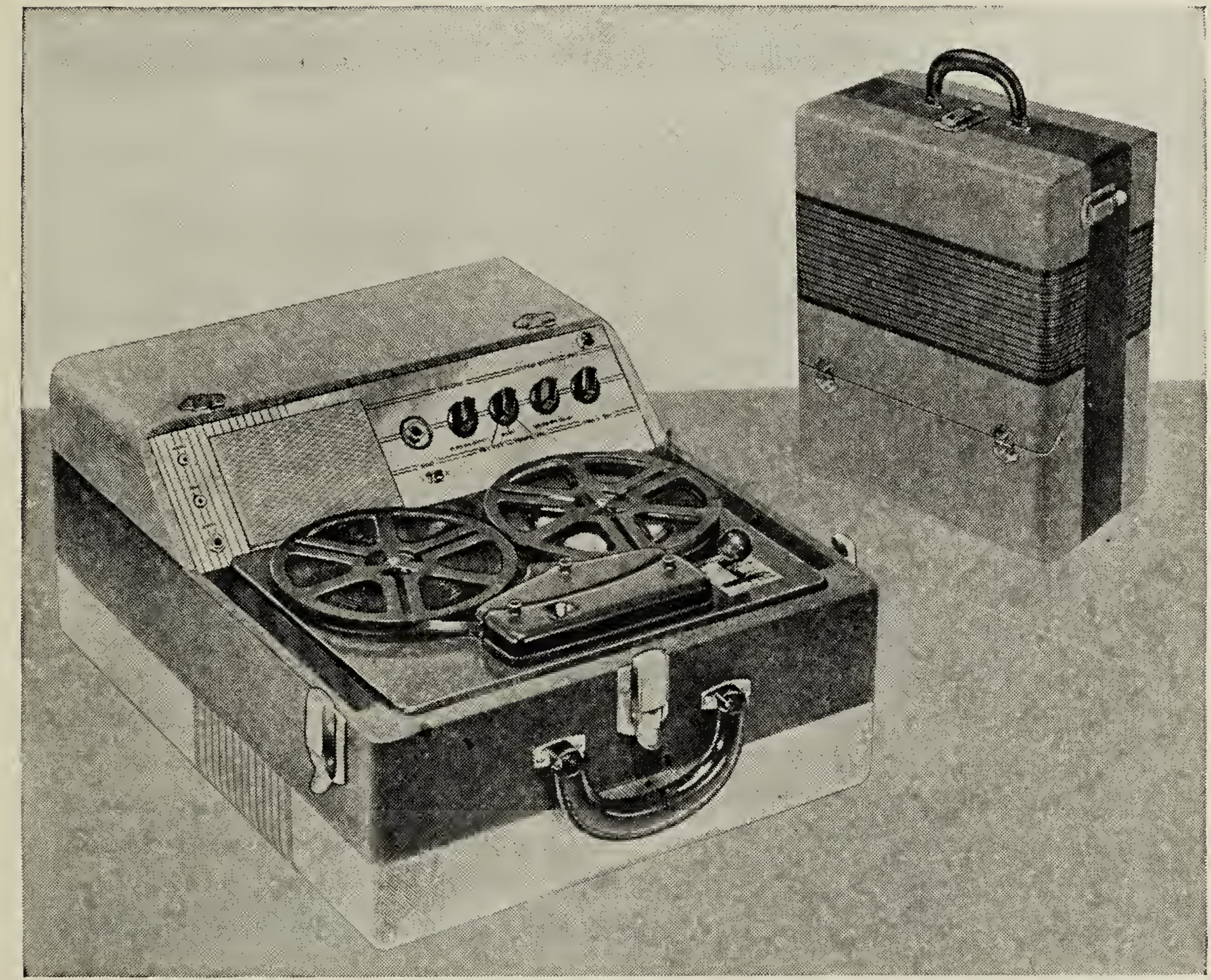

Fig. 58 A typical tape recorder. (*Brush Development Company.*)

The *film* recorder operates for a much longer recording time than disc, wire, or tape types and is used mainly for court room recording. Sound is embossed or grooved, both forward and in reverse direction on 35 mm film about 1000 feet in length. This produces a very long duration of recording time. Like the tape recorder, if playback of any particular part is desired the film must be "spotted" during recording and rewound to that portion. This recorder is very expensive but easy to operate, since the move per groove is automatic.

There are some advantages and disadvantages to all sound recorders and their playbacks. It would be unfair to expect everything in one instrument. The teacher, therefore, should consider some of the following:

(a) *Disc* recordings of good quality require skill and experience in setting the stylus and the pressure. This is not the case for the other recorders since they do not have a cutting head.
(b) *Wire* recorders can be moved, jostled, vibrated, during recording or playback, without effect on the quality of the program. Their compactness and lightness are also important if portability is desired.
(c) Sound can be recorded on *wire* and transferred to *disc* by "dubbing" if the equipment is properly matched.
(d) The *wire* cartridge cost per playing hour may be substantially less than for discs.
(e) *Tape* cannot twist since the same side always faces the recorder head. Therefore there is no resulting loss in magnetic strength or quality of the recording.
(f) *Tape* and *film* must be "spotted" during the recording if playback of any particular section is desired. It is also necessary to rewind the tape or film to the spotted section for any particular playback.
(g) Erasure can be carried out at any point in the operation of *wire* and *tape* recorders. This is not possible with *disc* recording.
(h) *Tape* can be "edited" by cutting and splicing desired sections together. This is not feasible with wire, disc or film.
(i) Storage is, in general, much less for spools of *wire* than for *tape, disc,* and *film* recordings.

Record Players

Various combinations of the components of a simple sound system may likewise be found in the selection of a record *player*. The present day popularity of the disc recordings has led to considerable competition in the field with resultant changes in types of players. The teacher should use considerable care in the selection of a player.

Players for school use are usually of the "two speed" type.

School and broadcast transcriptions play at a rate of 33⅓ revolutions per minute (rpm), while standard transcriptions play at 78 rpm. Another disc player is designed for operation at 45 rpm. Some players are designated as "constant speed" or "variable speed" players according to the accessories supplied for controlling the speed of the turntable.

There are various types of "Micro-Groove" players available. Some play at a turntable speed of 33⅓ rpm or 78 rpm or both. An automatic record changer in combination with this can hold 10—12 inch "Micro-Groove" records or 12—10 inch "Micro-Groove" records giving long playing time. But a special lightweight pick-up and a special radius needle are required for "Micro-Grooving."

The "45 rpm Record Player," like the "Micro-Groove" Player, also uses a needle radius about one-third that of the ordinary needle. The discs are 7 in. in diameter and have a spindle hole of 1½ in. diameter. Each disc is of a uniform size, is made of plastic, and is very thin so that there is considerable compactness in storage. Eight discs can be put on the turntable at one time. The playing time is 5 minutes on each side of the disc and the discs are automatically changed in one second. Two models are available, one of which can be wired to the speaker of a radio set, or one which is a complete sound system.

Public Address and School Sound

These sound systems are quite complex since many components of the simple system may be present. For example, there may be additional microphones, amplifiers, and speakers required for special needs, such as "paging," "on the spot" broadcasts, intercommunication, and simultaneous programming.

Public Address systems are either "simple fixed" or "portable" depending on the use to which the system is put. Some are used indoors, others are used outdoors. They are of high or low sensitivity, and, in some cases, are operated by remote control.

School sound systems are either "single input" (one microphone and one phonograph) or "dual input" (two microphones and one phonograph). Usually the "dual input" can be obtained with provision for "paging." Other systems may or may not have provision for "eavesdropping" although this is not often used.

In all such complex systems as these it is important that the microphones, amplifiers and speakers meet the *specifications* for "matching" the components. This is especially critical for microphones. Frequency response or frequency range should also be carefully considered because music, drama or just plain voice sounds over the system may be beyond the frequency range, giving a response that may be unfaithful or distorted.

Radio and Television

The technique of listening to radio and television programs, both in the home and school, is one of the most important skills of our modern age. With radio sets far surpassing in number other useful articles, the industry expends vast sums of money to study the reactions of the listening public. Some schools are now wired for sound so that almost any program on the radio can be "piped" into a classroom. And now television is moving rapidly into this field so

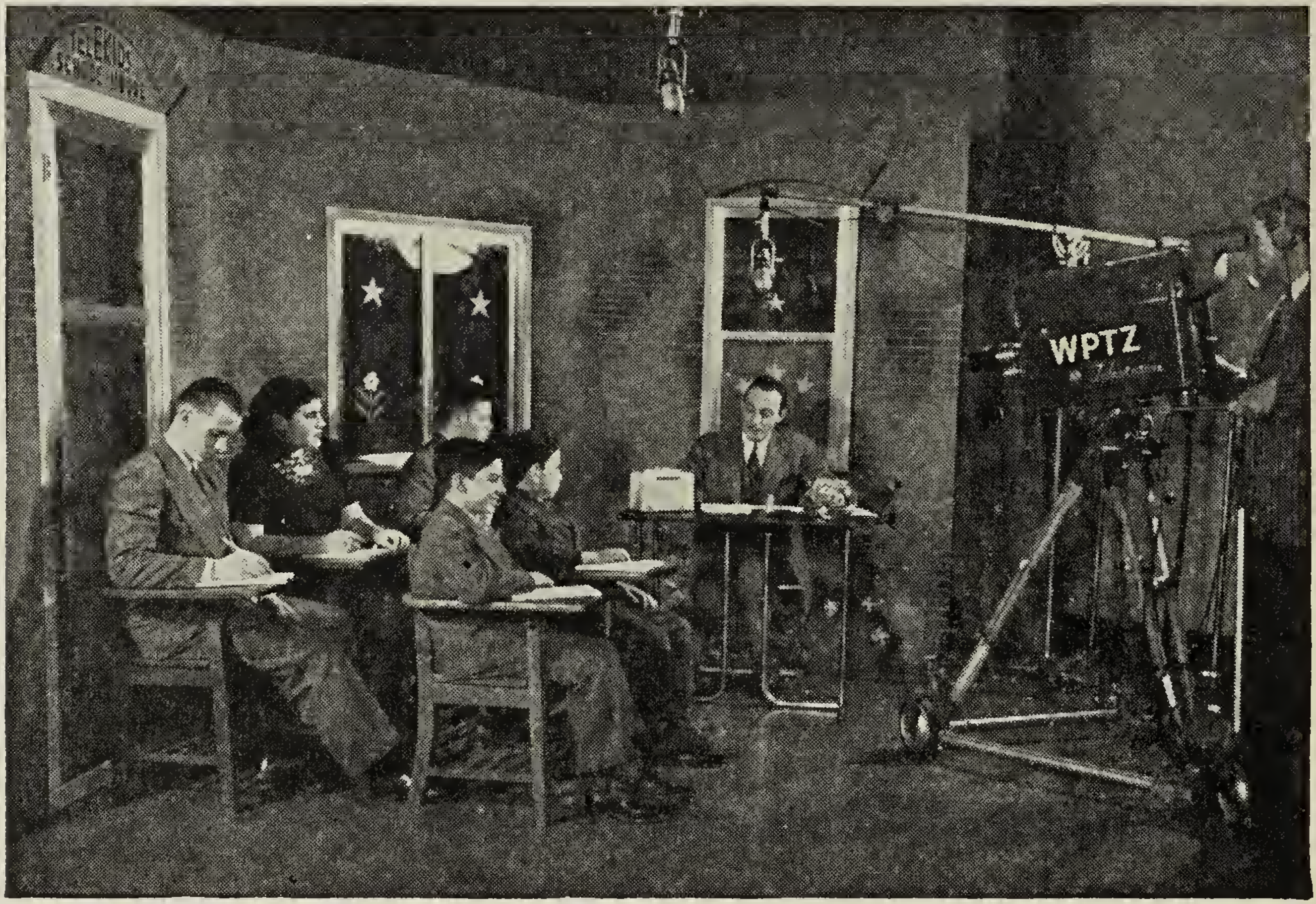

Fig. 59 Televising a Classroom. (*Philco Television Broadcasting Corp.*)

that educational features such as quiz programs are heard not only over the air but are seen as well.

Thus radio, which satisfies the ear, now combines with television to satisfy the eye as well. The tremendous educational effect of such a double-fold teaching media can be realized from such an example as that in Figure 60 showing a WPTZ telecast of the moon!

The teacher should realize that all the sound system problems of radio are present in television and that both are highly specialized in development. Therefore it is beyond the scope of this chapter to describe the technical aspects of such intricate sound systems. Also the teacher should realize that the radio and television stations require highly specialized personnel for operation and repair. The teacher, however, can cooperate with these modern teaching agents by helping to present the proper science programs and in the selection of science material "on the air." The teacher might carefully read the section devoted to "Radio Dramas" and "Televising Science Dramas" in Chapter 18 on Designed Materials.

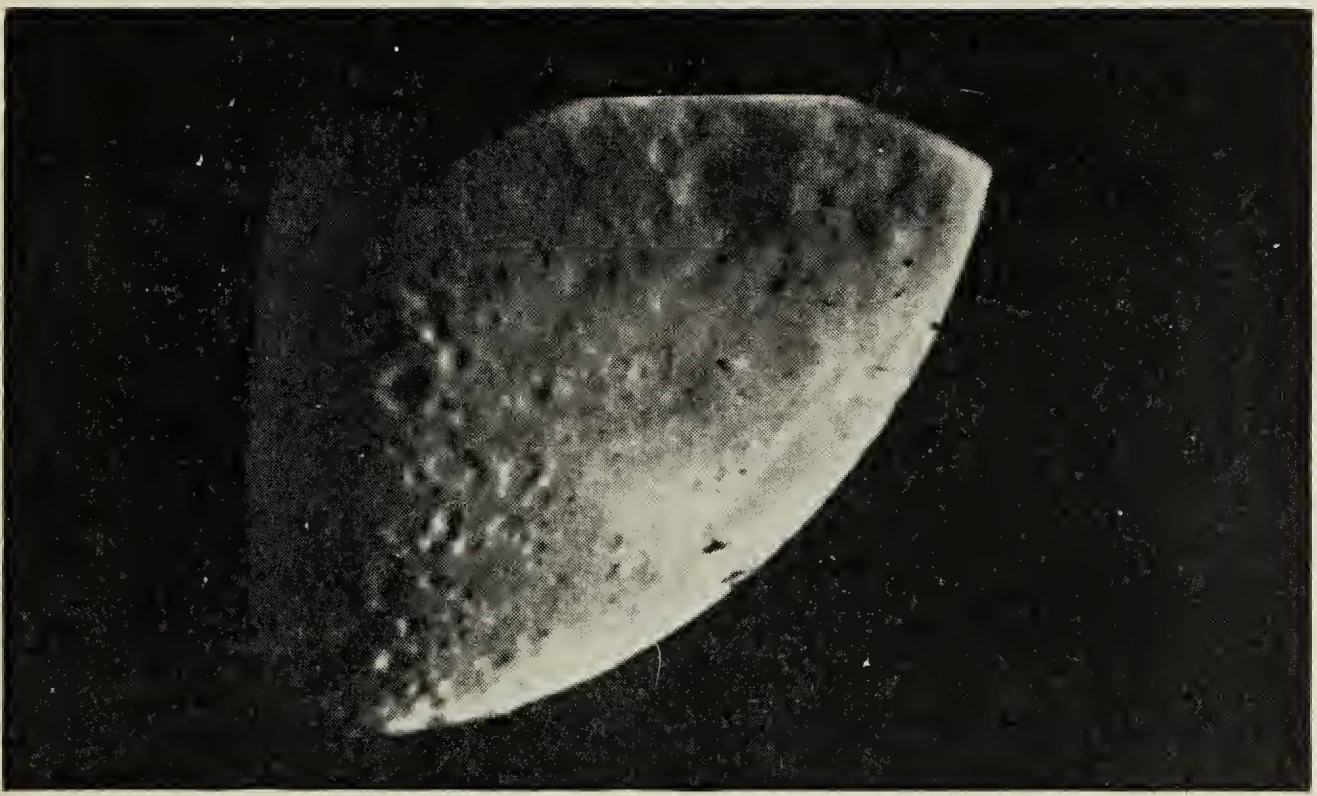

Fig. 60 Telecast of "A Trip to the Moon." (*Philco Television Broadcasting Corp.*)

In the schoolroom the teacher can apologize for a failure and repeat the demonstration. This is not the case for radio and television programs, so that whatever is said or done must be right the first time. If the teacher is coaching a group of students for a radio program, one of the previously mentioned recorders, with playback, would be useful for correcting speech and catching deviations from the script.

On the other hand, teachers making use of radio or television programs in the schools can now record these programs with one of the previously mentioned recorders. Stenographic or mimeographed copies of the playback can be made and distributed to the class. It is even possible to simultaneously photograph the images on the television screen and record the sound part on disc or wire or tape. In this way important programs can be copied in both sight and sound sequence, which can then be repeated in the classroom.

SOURCES OF SOUND SYSTEMS

Recorders and Players

Disc

Fairchild Camera and Instrument Corp., 88-06 Van Wyck Blvd., Jamaica 1, N. Y.
Meissner Mfg. Div., Maguire Industries, Inc., Mt. Carmel, Ill.
Presto Recording Co., 242 W. 55th St., N. Y. 19, N. Y.
Sound Scriber Corp., New Haven, Conn.
Speak-O-Phone Recording Equipment, 23 W. 60th St., New York 23, N. Y.
Radio Corporation of America, RCA Victor Div., Camden, N. J.
Rek-O-Kut Co., 38-01 Queens Boulevard, Long Island City, N. Y.
Victor Animatograph Corp., Davenport, Iowa
Webster-Chicago Corp., 5622 Bloomingdale Ave., Chicago, Ill.

Tape

Amplifier Corp. of America, 366–398 Broadway, New York 13, N. Y.
Brush Development Co., 3405 Perkins Ave., Cleveland, Ohio
Radio Corp. of America, R. C. A. Victor Div., Camden, N. J.
Sound Recorder and Reproducer Corp., 5501 Wayne Ave., Phila. 44, Pa.

Wire

Air-King Products Co., Inc., 1523 63rd. St., Brooklyn, N. Y.
Brush Development Co., 3405 Perkins Ave., Cleveland 14, Ohio
Electronic Sound Engineering Co., 4344 W. Armitage Ave., Chicago, Ill.
Moulded Insulation Co., 335 E. Price St., Phila. 44, Pa.
Pierce Wire Recorder Corp., 1328 Sherman Ave., Evanston, Ill.
Radio Corporation of America, RCA Victor Div., Camden, N. J.

Webster-Chicago Corp., 5622 Bloomingdale Ave., Chicago 39, Ill.
Wire Recording Corp. of America, 1331 Halsey St., Brooklyn 27, N. Y.
Wi Recorder, 7055 Intervale Ave., Detroit 4, Mich.

School Sound

Bell and Howell Co., 7100 McCormick R., Chicago 45, Ill.
DeVry Corporation, 1111 Armitage Ave., Chicago 14, Ill.
International Business Machines Corp., 590 Madison Ave., New York 22, N. Y.
Popular Science Publishing Co., Audio-Visual Division, 353 Fourth Ave., New York 10, N. Y.

SOURCES OF RADIO PROGRAMS

"Educational Radio Script and Transcription Exchange," Federal Security Agency, U. S. Office of Education, Washington, D. C.
"Service Bulletin of the FREC," Federal Radio Education Committee, U. S. Office of Education, Federal Security Agency, Washington 25, D. C.
"For the Student," Columbia Broadcasting System, 485 Madison Ave., New York, N. Y.
"NBC Presents," National Broadcasting Co., RCA Building, Radio City, New York, N. Y.
"The American School of the Air," Columbia Broadcasting System, 485 Madison Ave., New York, N. Y.
Radio Project, U. S. Department of the Interior, Office of Education, Washington, D. C.
National Association of Broadcasters, 1626 K Street N. W., Washington, D. C.

QUESTIONS AND EXERCISES

1. What are some "matching specifications" for microphones? For speakers?
2. What are meant by "feedback" and "scratch level" on the pick-up?
3. What are some causes of background noises in recorders?
4. Look up some technical information on "pick-ups," such as crystal, dynamic, inductance, capacitance or electronic types.
5. How can simultaneous programming take place in a school sound system?
6. How is "dubbing" performed?
7. Explain fidelity, distortion, and response as applied to a sound system.
8. How is "Micro-Grooving" done?
9. How does frequency-modulation (FM) differ from audio-modulation (AM)? Give advantages and disadvantages of FM and AM radio receivers or combinations.
10. What are some criteria for selecting the various components of a simple sound system?

11. What place do radio and television have in science education?
12. What are the names of some science programs now on the air?
13. What equipment does your classroom need for listening to radio programs?
14. How important is out-of-school listening to radio or seeing television?
15. Where can technical courses in radio and television be pursued?
16. What standards should the teacher use in judging a script for a science broadcast?
17. How would you select a program for your classroom?

PROJECTS

1. Visit a store selling various types of recorders or players. Pick out a recorder that you might wish to buy and list what data you can find about any of the following:
   A. Cost of the equipment
   B. Portability
   C. Flexibility
   D. Ease of Operation
   E. Permanence of recording
   F. Immediate play
   G. Length of recording and continuity
   H. Matching specifications
2. Make a trip to a radio station studio and note the following:
   A. Use of sound-effects recordings.
   B. Types of microphones used.
   C. Hand signals of the engineers and their meaning when a program is "On the Air."
   D. Materials used for the "dead" end of studio as compared to the "live" end.
   E. The script used and details of its make-up.
3. Visit a television studio and note the following:
   A. The view-finders and focussing of television camera and lens.
   B. The cueing of the performers by the stage manager.
   C. The monitor screens with fade in or fade out control.
   D. The "script rider's" control of the show.
   E. Hand signals to designate meanings, such as the "wind-up" of the performance.
   F. Microphone boom operation, or headphones and breast microphones, used.
   G. The use of "mock-ups."

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Appendix

SOURCES OF SENSORY AIDS

CORPORATIONS

Many corporations prepare a variety of materials which are useful in teaching science. Some corporations send out exhibits illustrating the processes of manufacture and the different commodities produced. They also prepare educational pamphlets[1] which frequently contain information and pictures useful to science teachers. Some of them have prepared excellent motion pictures which they loan to schools.

The following is a list of commercial firms that science teachers should write to for information.

Allis-Chalmers Mfg. Co., Advertising Department, Milwaukee, Wis.
Aluminum Company of America, 801 Gulf Bldg., Pittsburgh 19, Pa.
American Can Company, 230 Park Ave., New York, 17, N. Y.
American Society for Metals, 7301 Enclid Ave., Cleveland 3, Ohio
American Viscose Corp., 350 Fifth Ave., New York 17, N. Y.
Armstrong Cork Co., 295 Fifth Ave., New York 17, N. Y.
American Lime and Stone Co., Bellefonte, Pa.
American Plastics Corp., 50 Union Square, New York, N. Y.
Bell Telephone Company, Philadelphia, Pa.
Better Homes & Gardens, Des Moines, Ia.
Better Vision Institute, 630 Fifth Ave., New York 20, N. Y.
By-Product Ammonia, Educational Bureau, 50 W. Broad St., Columbus 15, Ohio
California-Grown Sugar Group, De Young Bldg., San Francisco, Calif.
Canadian National Railways, 673 Fifth Ave., New York 20, N. Y.
Caterpillar Tractor Company, Peoria 8, Ill.
Celanese Corporation, 180 Madison Ave., New York 16, N. Y.
Davey Tree Expert Company, Kent, Ohio
Department of Conservation & Development, Box 231, Raleigh, N. C.

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[1] The National Science Teachers Association, 1201 16th Street, N. W., Washington, D. C., sends several packets a year of these materials free to its members.

DeVry Corporation, 1111 Armitage Ave., Chicago, Ill.
Douglas Fir Plywood Association, Tacoma Building, Tacoma, Wash.
DuPont de Nemours & Company, 10th & Market Sts., Wilmington, Del.
DuPont Rayon Division, Empire State Building, New York 16, N. Y.
Eastman Kodak Company, 343 State St., Rochester, N. Y.
Eberhard Faber Pencil Company, 37 Greenpoint Ave., Brooklyn 22, N. Y.
Encyclopedia Britannica Films, 20 N. Wacker Drive, Chicago, Ill.
Ethyl Corporation, 405 Lexington Ave., New York 17, N. Y.
Fairchild Engine & Airplane Corporation, 30 Rockefeller Plaza, New York 20, N. Y.
Films Incorporated, 330 W. 42nd St., New York, N. Y.
Films of Commerce Co., Inc., 21 W. 46th St., New York, N. Y.
Ford Motor Company, Department of Photography, Dearborn, Mich.
Freeport Sulphur Company, American Bank Bldg., New Orleans, La.
Frosted Foods Sales Corporation, 250 Park Ave., New York 17, N. Y.
Garrison Film Distributors, Inc., 730 Seventh Ave., New York, N. Y.
General Electric Company, Visual Instruction Section, 1 River Road, Schenectady, N. Y.
G. E. X-ray Corporation, 2012 Jackson Blvd., Chicago, Ill.
General Motors Corporation, Public Relations Dept., 1775 Broadway, New York 19, N. Y.
Good Housekeeping, 959 Eighth Ave., New York, N. Y.
Goodyear Tire & Rubber Company, Motion Picture Department, Akron, Ohio.
Harvard Film Service, Biological Laboratories, Cambridge, Mass.
H. J. Heinz Company, Pittsburgh, Pa.
Ideal Pictures Corporation, 30 E. Eighth St., Chicago, Ill.
Illuminating Engineering Society, 51 Madison Ave., New York 10, N. Y.
Institute of Life Insurance, 60 E. 42nd St., New York, N. Y.
International Dental Health Foundation for Children, Inc., 130 East End Ave., New York, N. Y.
International Film Bureau, 59 E. Van Buren St., Chicago, Ill.
International Harvester Company, 180 N. Michigan Ave., Chicago, Ill.
Jam Handy Picture Service, Inc., 2900 E. Grand Blvd., Detroit, Mich.
Johnson & Johnson, New Brunswick, N. J.
King Cole's Sound Service, 203 E. 26th St., New York, N. Y.
Lilly Co., Indianapolis, Ind.
Linde Air Products Company, 205 E. 42nd St., New York, N. Y.
Lockheed Aircraft Corp., Burbank, Calif.
Mahogany Association, 75 E. Wacker Drive, Chicago 1, Ill.
Metropolitan Life Insurance Company, 1 Madison Ave., New York, N. Y.

Milk Industry Foundation, Chrysler Bldg., New York, N. Y.
Minnesota Valley Canning Company, Le Seur, Minn.
Modern Talking Picture Service, 9 Rockefeller Plaza, New York, N. Y.
National Association of Audubon Societies, 1775 Broadway, New York 19, N. Y.
National Association of Manufacturers, 14 W. 49th St., New York 20, N. Y.
National Better Light Bureau, 420 Lexington Ave., New York 17, N. Y.
National Dairy Council, 111 N. Canal St., Chicago, Ill.
National Fertilizer Association, Investment Building, Washington 5, D. C.
National Film Board of Canada, Ottawa, Ont., Canada
National Fire Protection Assn., 60 Batterymarch St., Boston, Mass.
National Parks Bureau, Ottawa, Ont., Canada
National Safety Council, 20 N. Wacker Drive, Chicago 6, Ill.
National Tuberculosis Association, 1790 Broadway, New York 19, N. Y.
New York Central Railroad System, 466 Lexington Ave., New York 17, N. Y.
Nu-Art Films, Inc., 145 W. 45th St., New York, N. Y.
Owen-Illinois Glass Company, Toledo 1, Ohio
Pan-American World Airways, 135 E. 42nd St., New York 17, N. Y.
Pepperell Mfg. Company, 160 State St., Boston, Mass.
Pittsburgh Plate Glass Co., 632 Duquesne Way, Pittsburgh 22, Pa.
Plomb Tool Company, Box 3519 Terminal Annex, Los Angeles 54, Calif.
Portland Cement Association, 33 W. Grand Ave., Chicago, Ill.
Pyrene Manufacturing Company, 560 Belmont Ave., Newark, N. J.
Quaker Oats Company, Advertising Department, 141 Jackson Blvd., Chicago, Ill.
RCA Manufacturing Company, Inc., Educational Department, Camden, N. J.
Ray-Bell Films, 2269 Ford Road, St. Paul, Minn.
Republic Steel Corporation, Extension Bureau, Cleveland, Ohio
Shell Oil Company, 50 W. 50th St., New York 20, N. Y.
Sinclair Refining Company, 10 W. 51st St., New York 20, N. Y.
Sperry Gyroscope, Motion Picture Dept., Manhattan Bridge Plaza, Brooklyn, N. Y.
Sun Oil Company, 1608 Walnut Street, Philadelphia, Pa.
Swift & Company, Union Stock Yards, Chicago, Ill.
Texas Company, 135 E. 42nd St., New York 117, N. Y.
Transcontinental & Western Air, Inc., 80 E. 42nd St., New York 17, N. Y.
United Fruit Company, Educational Department, Pier 3, North River, New York, N. Y.

U. S. Rubber Company, 1230 Sixth Ave., New York 20, N. Y.
U. S. Steel Corporation, 438 Seventh Ave., Pittsburgh 30, Pa.
Veneer Association, 616 S. Michigan Ave., Chicago 5, Ill.
Vermont Marble Company, 61 Main St., Proctor, Vt.
West Coast Sound Studios, Inc., 510 W. 57th St., New York, N. Y.
Western Electric Company, 195 Broadway, New York, N. Y.
Western Pine Association, Yeon Bldg., Portland, Ore.
Westinghouse Electric and Manufacturing Co., East Pittsburgh, Pa.
Westinghouse Elec. & Mfg. Company, 246 E. Fourth St., Mansfield, Ohio.
Weyerhauser Lumber Company, First National Bank Bldg., St. Paul, Minn.
Wholesome Films Service, Inc., 48 Melrose St., Boston, Mass.
Wilding Picture Sales Corp., 4925 Cadieux Rd., Detroit, Mich.
World Pictures Corporation, 729 Seventh Ave., New York, N. Y.

GOVERNMENT AGENCIES AND OTHER PUBLIC SERVICE ORGANIZATIONS

American Cancer Society, 350 Madison Ave., New York 17, N. Y.
American Museum of Natural History, 77th St. and Central Park W., New York 24, N. Y.
Bureau of Reclamation, Dept. of Interior, Washington 25, D. C.
Castle Films, 30 Rockefeller Plaza, New York 20, N. Y.
Coronet Instructional Films, 919 N. Michigan Ave., Chicago, Ill.
Encyclopedia Britannica Films, 20 N. Wacker Drive, Chicago, Ill.
Graphic Section, Bureau of Mines, 4800 Forbes St., Pittsburgh 13, Pa.
Motion Picture Service, Dept. of Agriculture, Washington, D. C.
State College of Agriculture, Cornell University, Ithaca, N. Y.
Teaching Films Custodians, 25 W. 43rd St., New York, N. Y.
Tennessee Valley Authority, Information Office, Knoxville, Tenn.
U. S. Department of Agriculture, Motion Pictures, Extension Service, Washington 25, D. C.
U. S. Department of the Interior, Bureau of Mines, Pittsburgh, Pa.
U. S. Office of Education, Federal Security Agency, Washington 25, D. C.
U. S. Public Health Service, Washington, 14, D. C.
U. S. Weather Bureau, Dept. of Commerce, Washington, 25, D. C.
Wild Flower Preservation Society, 3470 Oliver St., Washington, D. C.
Yale University Press Film Service, 386 Fourth Avenue, New York, N. Y.
YMCA Motion Picture Bureau, 347 Madison Ave., New York 17, N. Y.

EQUIPMENT FOR TEACHING VARIOUS SCIENCES

Suggested Equipment List for Chemistry

These lists were adapted from Bulletin No. 22, 1927. U. S. Dept. of Interior Bureau of Education, Washington, D. C.

List A—Desk Apparatus *(for 24 students)*

24 alcohol lamps, 4 oz. (or Bunsen burners).
24 blowpipes, brass, 8 inches.
12 reagent bottles, No. 108, for ammonium hydroxide.
12 reagent bottles, No. 106, for hydrochloric acid.
12 reagent bottles, No. 104, for nitric acid.
12 reagent bottles, No. 111, for sodium hydroxide.
12 reagent bottles, No. 102, for sulphuric acid.
24 burette clamps.
24 crucible tongs.
24 cylinders, plain 2 by 12 inches.
24 deflagration spoons, iron.
24 files, round, 4 inches.
24 files, triangular, 5 inches.
24 guaze squares, iron, asbestos centers, 5 inches.
24 mortars, with pestles, porcelain, 80 mm.
24 pneumatic troughs, galvanized armco iron.
24 ringstands, 2-ring.
24 sand baths, shallow, 4 inches.
24 test-tube racks.
24 tripods.

List B—Individual Apparatus *(for 24 students)*

24 asbestos sheets, 5 by 5 inches.
24 beakers, 100 cc.
24 beakers, 250 cc.
24 beakers, 400 cc.
24 crucibles, porcelain, No. 0.
24 dishes, evaporating, porcelain, 75 mm. No. 00A.
24 flasks, 250 cc.
24 flasks Erlenmeyer, 125 cc.
24 funnels, 75 mm.
24 gasometers, 50 cc.
72 glassplates, 10 by 10 cm.
24 graduates, cylindrical, 25 cc.
24 pipestem triangles, 2 inches.
24 pinchcocks, screw compressor.
24 rubber stoppers, 1 hole No. 1.
24 rubber stoppers, 1 hole No. 5.
24 rubber stoppers, 1 hole No. 4.
48 bottles, wide-mouthed, 2 oz.
72 bottles, wide-mouthed, 8 oz.
24 cobalt glassplates, 50 mm. by 50 mm.
24 rubber stoppers, 1 hole No. 8.
24 rubber stoppers, 2 hole No. 4.
24 rubber stoppers, 2 hole No. 8.
24 rulers, Eng. and met., 12 inches.
24 spatulas, horn, 150 mm.
24 burettes, 50 cc.
24 test tubes, ignition, 6 by ¼ inch.
24 test tube brushes.
24 test tube racks.
24 thermometers,—10° to 110° C.
8 thistle tubes.
24 watch glasses, 3 inches.

List C—Apparatus and Stock for General Use

24	aprons, rubber.
3	balances, trip scales, agate bearings.
3	sets weights, iron, on holder, 10–500 g.
6	hand balances, improved.
6	sets weights, in blocks, 1 ctg.–20 g.
48	bottles, wide-mouth, glass stoppers, 4 oz.
12	calcium chloride tubes, 6 inches.
12	combustion tubes, 45 by 1.9 cm.
12	combustion boats, porcelain, 60 by 10 by 10 mm.
12	condensers, Leibig, 15 inch.
12	condenser clamps.
12	condenser-clamp holders.
3	sq. ft. copper sheet, No. 30.
3	spls. copper wire, bare, No. 28, 4 oz.
3	pkg. corks, asstd. 0–11 (144).
3	cork borers (6 in set).
12	pkg. filter paper, 11 cm.
3	pkg. filter paper, 20 cm.
3	funnels, 125 mm.
12	funnels, separatory, with stopcock, 60 cc.
3	lbs. glass rods, 4–5 mm., asstd.
5	lbs. glass tubing, 5–7 mm., asstd.
3	hydrometers, universal.
3	hydrometer jars, 2 by 15 inches.
3	spl. iron wire, No. 28.
12	vials litmus paper, blue.
12	vials litmus paper, red.
8	magnifiers, tripod.
12	platinum loops, in glasshandles.
1	roll picture wire, No. 1 (25 yds.).
8	retorts, glass-stopper, 125 cc.
60	ft. rubber tubing, 3/16 inch.
30	ft. rubber tubing, 1/4 inch.
288	test tubes, Pyrex, 4 by 1/2 inch.
144	test tubes, Pyrex, 6 by 3/4 inch.
8	water baths, copper, 5 inches.

List D—Chemicals

2	lbs. acid, acetic, glacial, C.P.
12	lbs. acid, hydrochloric, C.P.
14	lbs. acid, nitric, C.P.
1	lb. acid, oxalic, crystals, comm'l.
1	lb. acid, phosphoric, ortho, 85 per cent C.P.
18	lbs. acid, sulphuric, C.P.
1	gal. alcohol, ethyl, denatured.
5	lbs. alum potassic.
1	lb. aluminum, metal turnings.
1	lb. aluminum, metal powder.
4	oz. arsenic, metal. cryst.
1	lb. arsenic trioxide, powder.
1	lb. ammonium nitrate, pure.
5	lbs. ammonium sulphate, comm'l.
5	lbs. ammonium sulphate, comm'l.
1	lb. ammonium sulphide, light.
2	lbs. ammonium carbonate, lumps. U.S.P.
2	lbs. ammonium chloride, pure, gran.
12	lbs. ammonium hydroxide, comm'l.
1	lb. antimony, metal, lump.
1	lb. barium chloride, C.P.
1	lb. barium nitrate, powder comm'l.
1	lb. barium sulphate, C.P.
4	oz. bismuth, metal.
4	oz. bismuth chloride, C.P.
1	oz. bismuth nitrate, C.P.
5	lbs. borax, cryst., pure.
2	cans bleaching powder (12 oz. can).

4 oz. cadmium sulphate, C.P., cryst.
2 lbs. carbon bisulphide, pure.
2 lbs. calcium chloride, annhyd. lumps.
2 lbs. calcium chloride, dry, granular.
2 lbs. calcium fluoride (fluospar) powder
5 lbs. charcoal, wood, lump.
2 lbs. charcoal, animal, powder
1 lb. chloroform, U.S.P.
4 oz. chromic chloride, C.P., green cryst.
4 oz. cobalt chloride, C.P.
1 oz. cobalt nitrate, C.P.
1 lb. copper chloride, C.P.
2 lbs. copper, metal foil, No. 36
2 lbs. copper, metal, turnings.
5 lbs. copper sulphate, cryst., comm'l.
4 oz. copper oxide, powd. black, C.P.
4 oz. copper oxide, wire, C.P.
2 oz. eosin.
1 lb. ether, U.S.P.
2 lbs. ferric chloride, U.S.P.
5 lbs. ferrous sulphate, cryst.
5 lbs. ferrous sulphide, gran.
1 lb. glycerine, C.P.
5 lbs. gypsum, lump.
2 lbs. hydrogen peroxide, 3 per cent hydrogen sulphide U.S.P. (make in laboratory).
2 oz. iodine, resub. cryst.
5 lbs. iron filings, clean.
5 lbs. iron powder.
2 sq. ft. lead, metal, sheet 1/64 inch.
2 lbs. lead acetate, cryst., comm'l.
2 lbs. lead nitrate, cryst., comm'l.
5 lbs. lime (quicklime), in tin can.
2 lbs. litharge, lead oxide, mono., yellow, pure.
4 oz. magnesium, ribbon.
2 lbs. magnesium, sulphate, C.P.
5 lbs. manganese dioxide, gran.
5 lbs. marble chips.
8 oz. mercury, metal.
4 oz. mercuric chloride, U.S.P.
4 oz. mercurous nitrate, C.P.
4 oz. mercuric nitrate, C.P.
8 oz. mercuric oxide, red, U.S.P.
4 oz. nickel nitrate (ous), C.P.
2 lbs. paraffin, medium.
4 oz. phenophthalein, U.S.P.
1 lb. phosphorus, yellow, sticks.
8 oz. phosphorus, red.
5 lbs. plaster of Paris.
1 lb. potassium bitartrate, U.S.P.
1 lb. potassium bromide, U.S.P.
5 lbs. potassium chlorate, cryst., pure.
2 lbs. potassium chromate, cryst.
2 lbs. potassium chloride, pure.
1 lb. potassium cyanide, pure.
1 lb. potassium dichromate, cryst.
1 lb. potassium ferricyanide, cryst.
1 lb. potassium ferrocyanide, cryst.
2 lbs. potassium hydroxide, tech., gran.
4 oz. potassium iodide, U.S.P.
2 lbs. potassium nitrate, pure, gran.
4 oz. potassium perchlorate, cryst., U.S.P.
2 lbs. potassium sulphate, C.P.
1 lb. rosin.
1 oz. silver, foil.
2 oz. silver nitrate, pure, cryst.
2 lbs. soda, common baking (sodium bicarbonate).
4 oz. sodium, metal.
2 lbs. sodium acetate, cryst., comm'l.
5 lbs. sodium chloride, fine, pure.
2 lbs. sodium carbonate, cryst., comm'l.

2 lbs. sodium hydroxide, sticks, U.S.P.
5 lbs. sodium nitrate, pure.
1 lb. sodium peroxide, C.P.
2 lbs. sodium sulphate, cryst.
8 oz. stannic chloride, C.P., cryst.
1 lb. stannous chloride, pure.
1 lb. strontium nitrate, pure.
2 lbs. sugar, cane (procure locally).
2 lbs. sugar, glucose (dextrose) lump.
5 lbs. sulphur, roll.
1 lb. tartaric acid, U.S.P., cryst.
1 lb. tartar emetic, pure.
1 lb. tin, metal, mossy.
2 lbs. zinc, metal, mossy.
2 lbs. zinc sulphate, pure, cryst.
2 lbs. zinc powder.
2 lbs. zinc strips.

List E—Reserve Stock

24 beakers, 100 cc.
24 beakers, 250 cc.
24 beakers, 400 cc.
36 bottles, glass stopper, 4 oz.
12 burettes, 50 cc.
12 cobalt glass plates, 50 by 50 mm.
24 crucibles, porcelain, No. 0.
3 cylinders, glass, 2 by 12 in.
24 dishes, evaporating, 75 mm.
24 flasks, 250 cc.
24 flasks, Erlenmeyer, 125 cc.
6 funnels, 75 mm.
3 graduates, cylindrical 25 cc.
6 doz. test tubes, hard, 6 by ¾.
24 thistle tubes.

Suggested Equipment List for Physics

List A—Apparatus for Students' Experiments

24 meter sticks, English and metric.
24 rulers, maple, English and metric, 30 cm.
3 vernier calipers.
3 micrometer calipers.
12 trip scales, with agate bearings.
12 sets weights, iron, slotted, with holder, 10–500 g.
3 sets specific gravity metal cylinders.
3 wooden cylinders, waterproofed.
3 wood blocks, rectangular, waterproofed.
3 wooden blocks, rectangular, loaded.
3 lead sinkers, about 175 g.
3 plumb bobs.
6 pressure gages.
30 ft. rubber tubing, ¼ inch.
12 overflow cans.
12 catch buckets.
4 Boyle's law apparatus, J tube.
24 prisms, hardwood for fulcrum.
4 hydrometers, for light liquids.
4 hydrometers, for heavy liquids.
24 spring balances, 2,000 g. 64 oz.
6 composition of force boards.
12 pulleys, single, bakelite.
12 pulleys, double, bakelite.
12 pulleys, triple, bakelite.
3 center of gravity blocks.
6 inclined planes, with graduated arc.
6 Hall's cars, or inclined plane.
3 wheel and axle, aluminum.
12 resonance tubes, glass, 4 by 45 cm.
12 thermometers, —10° to 110° C.
12 air thermometer bulbs, 50 mm.
3 planes, grooved, with steel ball and powder.
12 steam generators.

12 calorimeters, nickeled brass, 75 by 125 mm.
12 tuning forks, C, 128
12 tuning forks, C, 256.
2 vibrographs (fork-rating apparatus).
2 tuning forks, for above.
24 mirrors, plane, 4 by 15 cm.
12 refraction plates, glass, 7 by 7 cm. by 6 mm.
12 refraction plates, triangular, 75 mm. faces by 7 mm.
6 optical benches.
12 lenses, convex, 15 cm. focus.
12 lenses, convex, 10 cm. focus.
12 prisms, equilateral, 75 mm. with 28 mm. faces.
3 lodestones.
6 rods, soft steel for magnetizing in earth's field, 6 mm. by 10 cm.
24 bar magnets, 1 by 1 by 15 cm.
12 magnets, U-shape.
24 magnet compasses, 25 mm.
24 dry cells.
12 voltaic cells, students' single fluid.
3 dip needles.
6 galvanoscopes.
6 bot. iron filings (4 oz.) in shakers.
12 electromagnets.
4 telegraph sounders, 4 ohm.
4 telegraph keys.
4 telegraph relays.
12 electric bells, 2½-inch gong.
2 electrolysis apparatus, battery-jar type.
2 storage cells.
4 resistance boxes, standard, 0.1–111 ohms.
6 D'Arsonval galvanometer, jeweled pivots.
4 ammeters, DC, double range, 0–3 and 0–30 amps.
4 voltmeters, DC, 0–150 v. in l.v. divisions and 15 v. in 0.01 volt divisions.
4 Wheatstone bridges.
2 commutators, simple form.
24 coils of wire, DC, 40 turns No. 24.
2 speed indicators.
6 electroscopes.
6 Leyden jars, pint.
6 friction rods, vulcanite, 25 cm.
6 friction rods, glass, 25 cm.
48 pith balls.
4 cat skins, half.
3 fish lines (card).
4 telephone transmitters.
4 telephone receivers.
12 ringstands, 3-ring.
12 test-tube clamps.
24 double connectors, brass.
24 jars, battery, 150 by 200 mm.
24 marbles, glass, ¾-inch.
24 thistle tubes, 30 cm. stem.
12 barometer tubes, thick wall, 80 cm.
3 ball and ring.
3 linear expansion apparatus, lever type.
24 candles, paraffin, 12's.

List B—Tools, Stock, and Supplies

6 knife switches, single throw, single pole.
6 knife switches, double throw, double pole.
24 asbestos squares, 6 inch
2 sets cork-borers, 1–3.
24 wire gauze squares, 5 inch.
24 pinchcocks, screw compression.
6 spls. copper wire, No. 24 (4 oz. spls.).

6 spls. copper wire, DCC, No. 28 (4 oz. spls.).
3 lbs. copper annunciator wire, No. 18.
3 spls. German silver wire, bare, No. 28 (4 oz. spls.).
3 spls. iron wire, bare, No. 28 (4 oz. spls.).
3 spls. piano wire, No. 2.
3 rolls piano wire, No. 9 (4 oz. roll).
3 spls. piano wire, No. 7.
3 spls. piano wire, No. 5.
1 spl. fuse wire, ½ ampere.
1 spl. fuse wire, 1 ampere.
1 spl. fuse wire, 2 ampere.
1 spl. fuse wire, 5 ampere.
6 files, round, 6 inch.
6 files, triangular, 6 inch.
2 wrenches, monkey, 8 inch.
3 pliers, side cutting, 5 inch.
3 pliers, round nose, 6 inch.
3 screw drivers, small, 4 inch.
3 screw drivers, large, 8 inch.
3 hammers, claw, 7½ oz.
3 snips, metal, 2½ inch cut.
3 pkgs. corks, asst. 0–11 (144).
12 graduates, cylindrical, 100 cc.
6 graduates, cylindrical, 250 cc.
3 lbs. rubber stoppers, 2 hole, 0-0 asstd.
36 ft. rubber tubing, 3/16 inch.
36 ft. rubber tubing, 3/16 inch.
9 lbs. glass tubing, 5 mm.
6 spls. spring brass wire, No. 22.
6 spls. spring brass wire, No. 28.
3 soldering sets.
24 bottles, glass stopper, for reagents, 4 oz.
12 lamp chimneys, students'.
12 hydrometer jars, 15 x 2 inches.
9 flasks, 250 cc., Pyrex.
12 funnels, 90 mm.
3 lbs. thermometer tubing.
3 sq. ft. copper sheets, No. 20.
3 sq. ft. lead sheet, 1/16 in. thick.
3 sq. ft. zinc sheet, 1/16 in. thick.
27 lbs. acid, sulphuric, comm'l.
15 lbs. copper sulphate, cryst., tech.
6 lbs. ether, sulphuric, U.S.P.
9 lbs. mercury.
6 lbs. nickel ammonium sulphate, comm'l.
6 lbs. paraffin, hard.
15 lbs. potassium bichromate.
6 lbs. sulphur, roll.
3 lbs. vaseline (petrolatum), yellow.
6 lbs. zinc sulphate.
12 Bunsen burners.

List C—Classroom Demonstration Apparatus

(Suggested minimum list)

2 cohesion plates, glass.
1 capillary tube, set of 7, mounted.
1 osmometer.
1 membrane.
1 table rotator (see motor-rotator, List D).
1 centrifugal hoop.
1 acoustic and color disk.
1 second law of motion apparatus.
1 lift pump, glass model.
1 force pump, glass model.
1 Pascal's vase, with metallic diaphragm.
1 air pump and plate on one base.
1 bell jar, 2 gallon.
1 jar vacum wax.
1 seven-in-one apparatus (spirometer).
1 barometer tube with mercury well.

1 barometer, aneroid.
1 barometer, mercurial, Fortin principle.
1 compound bar.
1 steam engine model.
1 electrophorus.
1 electromagnet, lifting.
1 induction coil, demonstration, 6 mm.
1 wire spiral, showing wave motion.
1 organ pipe with movable piston.
1 optical disk.
1 disk illuminator.
1 hydraulic press, glass model.
1 seconds pendulum, with mercury contact.
1 sonometer.
1 motor, shunt wound, 110 v. D.C., m.h.p.
1 motor brake and mounting.

List D—Additional List of Demonstration Apparatus

(Selections should be made from this list as needs require and funds permit)

1 elasticity of flexure apparatus, contact method.
1 torsion apparatus.
1 motor-rotator, 110-v. A.C. motor.
1 centrifugal globe.
1 Arago's magnetic rotation apparatus.
1 gyroscope (medium size).
1 sand pendulum.
1 Magdeburg hemisphere.
1 water motor, demonstration.
1 Boyle's law apparatus.
1 rotary blower, electric, 110-v. A.C.
1 rotary vacuum pump.
1 vacuum tube.
1 bell in vacuo.
1 coin and feather tube.
1 manometer for air pump.
1 maximum density of water apparatus.
1 radiometer.
1 mechanical equivalent of heat tube.
1 gas engine, model.
1 static machine.
1 Leyden jar, dissectible.
1 discharger.
1 set Geissler tubes (6) 15 cm. long.
1 contracting helix.
1 earth induction coil.
1 induction coil, 1 in. spark.
1 alternating current apparatus.
1 galvanometer, lecture table.
1 galvano-volt-ammeter (six-in-one).
1 lamp board resistance, 5 lamp.
1 electrolysis apparatus, improved, Hoffman.
1 sympathetic vibrating bar.
1 pr. singing tubes, Knipp's small form.
1 refraction tank for use with optical disk.

Suggested Equipment List for Biology

Individual Apparatus

12 battery jars, clear white glass, 5 by 7 inches.
48 bottles, wide mouth, 8 oz.
24 bottles, cyanide.
48 beakers, 250 cc.
24 dishes, crystallizing, 100 mm.

24 dishes, evaporating, 90 mm., No. 2.
24 dissecting sets, 6 pieces in case.
24 dissecting pans, wax bottom.
24 pkg. filter paper, 15 cm.
24 flasks, 250 cc.
24 glass plates, 4 by 4.
24 microscopes, dissecting.
24 pinchcocks, screw compression.
24 pneumatic troughs.
24 ring stands, 3 ring.
24 rubber stoppers, 2 hole, No. 3.
24 rubber stoppers, 2 hole, No. 8.
24 test tubes, hard, 6 by ¾.
48 thistle tubes.
96 watch glasses, 3 inches.
24 wire gauze squares, 5 inches.
12 Bunsen burners.
36 ft. rubber tubing, ¼ inch.

General Apparatus

2 aquariums, frame, 3 gal.
2 bell jars, open top, 1 gal.
2 bell jars, 3 gal.
2 bladders, for osmosis.
4 bottles, wide mouth, 16 oz.
1 pr. bone forceps, 190 mm. long.
2 trip scales, agate bearings.
2 iron weights, 10 g. to 500 g.
2 corks, asstd. 0–11 (144).
2 cork borers, set of 6.
2 corrosive sublimate tablets.
6 flasks, 500 cc.
100 flower pots, paraffined paper, 3 inches per C.
6 funnels, 75 mm.
2 funnels, 6 inches.
3 lbs. glass tubing, 5–7 mm. asstd.
6 lbs. glass tubing, 8 to 13 mm. asstd.
2 graduates, cylindrical, 250 cc.
2 insect nets, collapsible.
200 insect pins, No. 0, per C.
200 insect pins, No. 3, per C.
2 insect spreading boards, 12 by 4⅞ inches.
8 litmus papers, blue.
8 litmus papers, red.
24 medicine droppers.
40 petri dishes, 50 mm.
24 rubber stoppers, 1 hole, No. 2.
24 rubber stoppers, 2 hole, No. 9.
36 ft. rubber tubing, 3/16 inch.
36 ft. rubber tubing, ¼ inch.
3 sq. ft. rubber dam.
144 test tubes, 4 by ½, per 12.
144 test tubes, 6 by ¾.
24 test tube brushes.
12 test tube racks.
6 thermometers, 110° C. and 220° F.
6 tripods, 6 inches.
2 vasculum, collecting case.
1 water bath, copper, constant water level, 6 inches.

Additional General Apparatus

(Selections should be made from these lists according to requirements and funds)

1 air tester, for CO_2.
2 microscopes, compound, 2 oculars, 2 objectives, double, nose piece, in case.
2 gr. microscope slides, blanks, 3 by 1 inch.
2 gr. microscope cover glasses, round, No. 2, 18 mm.
1 microtome, hand.
1 Pasteurizing outfit.
1 set prepared slides, botany (25 in box).

1 set prepared slides, physiology (25 in box).
3 staining jars.
1 section razor.
1 sterilizer.

Models and Charts

1 model, anatomical, human skull and brain.
1 model, anatomical, human ear.
1 model, anatomical, human torso.
1 set physiology, anatomy and hygiene charts.
1 set botany charts, beginners.
1 set natural history and mineralogy charts.
1 set life histories of insects, squash bug, cotton boll weevil, apple borer, cucumber codling moth, peach borer, lady bug, honey bee, silkworm, etc.

Chemicals and Stains

1 lb. acid acetic, glacial, C.P.
2 lbs. acid hydrochloric, comm'l.
2 lbs. acid nitric, comm'l.
8 lbs. ammonium hydroxide, comm'l, 26°.
8 ozs. Benedict's solution, qualitative.
2 ozs. Canada balsam for mounting slides.
2 lbs. calcium phosphate (bi-monobasic), C.P.
2 lbs. calcium phosphate (mono), comm'l.
2 lbs. calcium sulphate, plaster Paris.
8 ozs. carbolic acid (loose cryst.).
2 lbs. charcoal (lumps), wood.
10 gms. eosin, yellowish (water soluble).
2 lbs. ether, U.S.P.
2 lbs. ferric chloride, U.S.P.
10 lbs. formalin.
8 ozs. iodine solution in potassium iodide.
2 lbs. lime water.
12 ozs. lysol.
2 lbs. magnesium sulphate, U.S.P.
2 lbs. manganese dioxide.
20 gms. malachite green.
2 lbs. paraffin, med.
8 ozs. potassium bichromate, C.P.
2 lbs. potassium chlorate, cryst., pure.
2 lbs. potassium nitrate, pure.
2 ozs. pepsin, powder.
2 ozs. pancreatin.
2 lbs. sodium carbonate, comm'l.
2 lbs. zinc, mossy.
2 lbs. zinc chloride, pure, gran.

Suggested Equipment List for General Science

Student Apparatus (Class of 24)

15 test tubes, hard, Pyrex, 16 mm.
120 test tubes, 6 by ⅝ inches.
15 test-tube brushes.
15 lbs. glass tubing, 6 mm.
48 ft. rubber tubing, 3/16-inch.
6 ft. rubber tubing, heavy wall, ¼-inch.
12 files, triangular, 5 inches.
15 bottles, wide mouth, 4 oz.
15 bottles, wide mouth, 8 oz.
30 beakers, 100 cc.
6 beakers, 250 cc.
24 rubber stoppers, No. 1, one-hole.
24 rubber stoppers, No. 3, two-hole.

24 rubber stoppers, No. 5, two-hole.
24 rubber stoppers, No. 7, two-hole.
12 rubber stoppers, two-hole, assorted, No. 8-13.
15 ring stands, 5 by 8 base.
15 ring-stand rings, 3-inch.
15 ring-stand clamps, right angle.
24 flasks, Erlenemeyer, 125 cc.
15 dry cells.
12 thermometers, double scale, 110° C. and 220° F.
15 funnels, glass, 40 mm.
15 thistle tubes.
7 bar magnets, 1 by 1 by 15 mm.
8 horseshoe magnets, 4-inch.
1 spl. copper wire, DCC, No. 22 (1 lb.).
1 spl. copper wire, DCC, No. 30 (1 lb.).
18 meter and yard sticks.
12 push bottons.
12 magnifying glasses.
1 trip scale.
6 sets weights, brass in block, 1–500 g.
15 evaporating dishes, porcelain, 3-inch, No. 00A.
12 electric bells, 2½-inch gong.
15 single pulleys, bakelite.
10 double pulleys, bakelite.
12 lenses, 20 cm. focus.
4 prisms, 75 mm. long.
15 magnetic compasses, 10 mm.
15 forceps, laboratory, 5-inch.
15 test-tube holders (wire clamp).
12 petri dishes, 75 mm.
12 mirrors, plane, 10 by 10 cm.
5 mirrors, convex, 4 cm.
12-wire gauze (5-inch squares).
1 pkg. corks, assorted, 0–11 (144).
1 pkg. corks, assorted, 12–26 (144).

Demonstration Apparatus

1 air pump, good grade, vacuum and pressure combined.
1 air-pump plate, with stopcock.
1 bell jar, fitted for stopcock.
1 stopcock for bell jar.
1 barometer tube, 80 cm. long.
1 barometer aneroid.
1 tuning fork, C′, 256 vps.
1 tuning fork, F′, 320 vps.
1 tuning fork, G′, 384 vps.
1 tuning fork, C″, 512 vps.
1 microscope, divisible objective.
1 force pump, glass model.
1 lift pump, glass model.
6 U-tubes, for distilling, 8 inches.
1 set borers (6 in set).
1 electrolysis apparatus, battery jar type.
1 St. Louis motor.
1 field for St. Louis motor.
1 graduate, cylindrical, 250 cc.
5 graduates, cylindrical, 50 cc.
1 model of steam engine.
1 dry-bulb thermometer.
1 wet-bulb thermometer.

Suggested but Not Essential

1 ammeter, battery type, 0–35 amps.
1 voltmeter, battery type, 0–10 volts.
1 aspirator, filter pump, for ¼-inch I.P. (Coupling to be ordered according to conditions.)
1 aquarium, glass jar, round, 7 by 7 inches.
1 telegraph key.
1 telegraph sounder.
1 pony relay, 20-ohm.

Chemicals and Supplies

24 candles, paraffin, 12's.
3 sq. ft. rubber dam.
4 ctn. iron filings (each 4 oz. with sifter tops).
1 vial litmus paper, blue.
1 vial litmus paper, red.
6 pkg. filter paper, 9 cm.
1 sq. ft. aluminum sheet, No. 20.
1 sq. ft. lead sheet, $\frac{1}{32}$-inch.
1 gal. alcohol, denatured.
1 qt. alcohol, wood, 95 per cent.
9 lbs. acid, sulphuric.
6 lbs. acid, hydrochloric.
7 lbs. acid, nitric.
5 lbs. mercury.
1 lb. potassium chlorate.
1 lb. zinc, mossy.
1 lb. manganese dioxide.
2 lbs. starch, corn.
1 lb. starch, wheat.
1 lb. starch, potato.
1 oz. iodine, resubl., U.S.P.
1 lb. ammonium hydrate.
1 lb. ether, sulphuric.
1 lb. sodium bicarbonate (baking soda).
5 lbs. sulphur, flowers.
1 lb. paraffin, med.
4 oz. phosphorus, yellow (can be shipped by frt. only).
1 lb. carbon tetrachloride, pure.
1 lb. copper, metal filings.
1 lb. tin, gran.
1 oz. silver nitrate.
1 pt. turpentine, spirits.
1 lb. ammonium nitrate, pure.
1 lb. cream of tartar, U.S.P.
5 lbs. copper sulphate.
1 lb. sodium hydroxide, sticks.
1 lb. Rochelle salt.
1 lb. borax

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